THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE IV. VOL. X.

No. IV.—APRIL, 1903.

ORIGINAL ARTICLES.

I.—The Development of River Meanders.

By Professor W. M. Davis, Harvard University, Cambridge, Mass.

THE paper by Dr. Callaway, "On a Cause of River Curves," in the Geological Magazine for October, 1902, suggests comment for two reasons: first, because the cause that he brings forward seems of doubtful application; second, because the habitual entrance of branch streams at a certain part of the curves of main streams is satisfactorily explained by controls which seem to be of surer and more powerful application than the control which he advocates.

In ascribing to a tributary the power to make a main stream bend in a definite manner towards the tributary, and thus determine the habitual entrance of tributaries on the convex side of the main stream's curves, Dr. Callaway argues that the detritus brought by the tributary will be deposited on the further side of the main stream and somewhat below the tributary's mouth. Various examples known to me of the deposits formed by side streams in the channels of main streams do not bear out this conclusion: the detritus is not deposited on the further side of the main stream, but as a delta at the mouth of the tributary or a little below it; and the main stream does not bend toward, but away from the tributary. The Rhine, the Colorado, and many other rivers that might be instanced, show abundant examples of this kind. Moreover, the assumption of an initially straight main river, as stated by Dr. Callaway, involves an extreme improbability. Rivers cannot be habitually straight in their initial stage, and the bends with which they begin are as a rule spontaneously exaggerated in their later development. The processes by which the initial bends are developed into meanders, and by which the meanders are persistently maintained when once developed—entirely independently of the action of tributaries,—are too important to be omitted from the problem in hand: above all, they should not be replaced by a doubtful or at most a weak process.

The most important process in the development of river meanders is the displacement of the line of fastest current by inertia from mid-channel toward the outside of every curve. As a result erosion tends to take place on the outside and deposition on the inside of the curve. This process is self-perpetuating. However slight the initial bends, they will be increased; and as the valley floor is broadened the curves will be developed into systematic meanders of increasing radius and breadth, as in Fig. 1. The only conditions under which the river course will tend to straighten itself are: strong tilting in the direction of river flow, and downward erosion upon a weak stratum between two resistant strata in an inclined structure. Both these conditions are only temporary; for as grade is reached in either case and the valley floor is widened, the residual departures from a perfectly rectilinear course will be exaggerated again, and in advanced maturity the river must always be curved. The smaller the stream, the greater the effect of accidental causes, such as falling sods and trees, tributary deltas, etc., in forming new bends. The larger the river, the greater the effect of inertia in exaggerating pre-existant bends and in overcoming local or accidental irregularities.

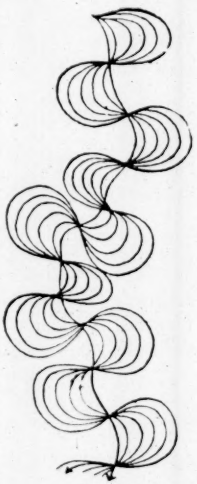

FIG. 1.

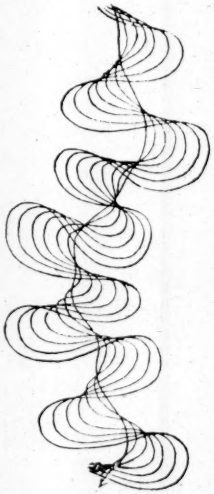

FIG. 2.

A river not only tends to increase its meanders; it also tends to push the whole meander system down the valley. This is because the line of fastest current, displaced toward the outside of each curve, enters the succeeding curve (or stretch between two curves) near the down-valley bank, which is therefore worn away, while the opposite up-valley bank is built out. As a result, Fig. 1 should be modified by a persistent down-valley migration of every bend, as in Fig. 2. Cut-offs occur now and then, here and there, but the shortened course at a cut-off is not straight, and its faint curves are

soon systematically exaggerated into meanders again. Abundant verification can be given of this scheme of development, by observing the behaviour of actual rivers, or more simply by studying the new edition (1900–1901) of the preliminary maps published by the Mississippi River Commission at St. Louis, Missouri, on which the river channels as determined by surveys in 1893–5 are over-printed in red upon the results of surveys in 1881–3, printed in black.

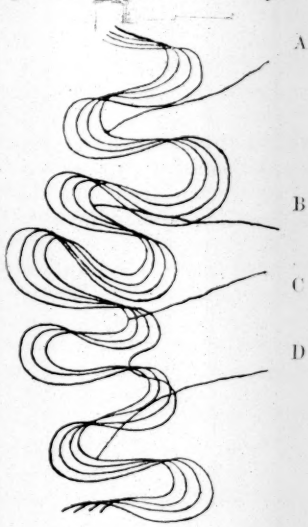

FIG. 3.

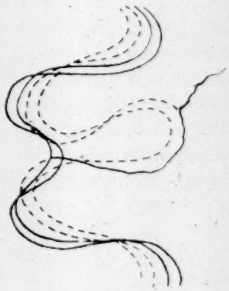

FIG. 4.

Any river that we now see meandering in an open alluvial plain must have been meandering a long time. Its individual meander curves must have already advanced down the valley over considerable distances; and it is, I believe, chiefly for this reason that tributaries are taken in where the main stream bends toward them. To make this clear, let a number of tributaries be added at random to the latest river course, drawn in Fig. 2. Four of them are shown in Fig. 3: one enters the river at a convex bend, the other three at or near concave bends. Now let the normal changes of the meanders continue still farther, as in the dotted lines of Fig. 4. In the first of these changes, tributary D is taken in by the convex curve next above the concave curve that it entered before. In the second change, the mouth of the tributary B is similarly transferred to a convex curve. In the third change, the same fate overtakes tributary A. During all these changes, tributary C has been only a little shortened; it still enters on a convex curve. When this curve comes to move down the valley the tributary will prolong its course, but will continue to enter the main stream on the up-valley side of a curve, until it is captured by the approach of the next following curve. It therefore appears natural enough that tributaries should usually

enter the main river meandering freely on a flood plain where its curves turn toward them.

The simplest conditions under which a tributary should be led to enter its master at an abnormal point are found in the occurrence of a cut-off, as in Fig. 4; but this special case would soon be brought under the rule, either by the development of a new meander which will usually grow towards the tributary in the neighbourhood of the cut-off,[1] or by the approach of the next up-valley meander.

A second group of examples would include rivers that follow relatively narrow meandering valleys, like those of the lower Wye, the lower Seine, the lower Moselle, or the north branch of the Susquehanna. Here the same rule may be expected to apply to the entrance of the tributaries, and that for two reasons. In the first place, because such rivers have, it may be said with much confidence, incised their meandering valleys from a meandering course that they formerly possessed on the upland in which the valleys are incised, when that upland was a lowland of erosion. On such a lowland the rivers must have reached a late stage of their cycle of development, and in a late stage they must have been meandering freely. While the uplift was going on and afterwards, the meanders would have been incised beneath the uplifted lowland; but the entrance of the tributaries has not been thereby significantly altered from whatever orderly arrangement they had gained during the former lowland stage of erosion.

In the second place, if by chance any abnormally entering tributary existed when uplift and incision began, the normal processes of widening the meander belt and of shifting the meanders down-valley, which must accompany incision, would sooner or later bring about a normal entrance in the same manner as on an alluvial flood plain, shown on Fig. 3, but at a lower rate than there obtains. An excellent instance of this kind is known in the lower Seine, where the Ste. Austreberte has been taken in at Duclair, not far below Rouen, precisely as illustrated in Fig. 3.

Another instance of the same kind occurs on the Marne not far east of Paris (see "The Seine, the Meuse, and the Moselle," Nat. Geogr. Mag., 1896, vii, 191). The Moselle exhibits at least one illustration of the entrance from the south-east of a small tributary, the Veldenzer Bach, on a concave stretch a short distance up-stream from Berncastel; but this is demonstrably the result of a cut-off, as shown in Fig. 4 (ibid., pl. xxii, opp. p. 193).

These normal, effective, and fully verified habits of change in the course of a meandering river seem to account very fully for the rule that tributaries usually enter where the river curves toward them; a rule that Mr. Callaway shows to obtain for various rivers in many parts of the world, and that is supported by certain additional examples that I have recently inspected.

[1] The changes following the occurrence of a cut-off, as illustrated on the maps of the Mississippi, show that the growth of a new meander towards the cut-off and abandoned meander, but a little further down-valley, is not unusual.

II.—Creechbarrow in Purbeck.—No. 2.[1]

By W. H. Hudleston, M.A., F.R.S., F.G.S.

Additional Points in Stratigraphy.

In my paper published in the Proceedings of the Dorset Field Club (vol. xxiii), I dwelt at some length on certain borehole sections made towards the northern base of Creechbarrow with a view to the discovery of Pipeclay. This course was adopted in the hope that a study of these sections might throw some light on the stratigraphical relations between the Creechbarrow Beds on the hilltop and the Pipeclays lower down, if indeed there are any stratigraphical relations beyond a mere jumble of irregular deposits whose precise orientation can never be disentangled. Whether this latter supposition is the true one or not, the exceptional character of the Creechbarrow Beds, as a local feature, remains the same, even although we cannot decide whether they go under, over, or into the Pipeclay series. Before attempting any further speculation as to the possible stratigraphy of the region I will call attention, at any rate, to its topography as shown in the accompanying figure.

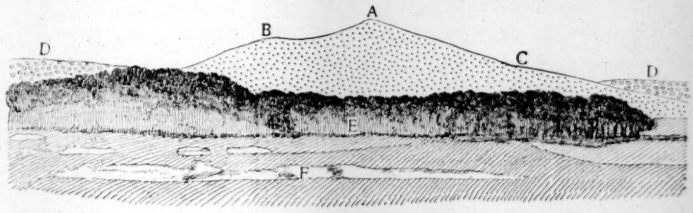

Fig. 1.—Creechbarrow from the north-east, based on a photograph by the late Mr. Laurence Pike.

A. Summit of Creechbarrow, 637 feet.
B. The eastern spur.
C. The northern ridge (approximate dip slope). The hilltop limestone extends along this ridge as far as the 500 feet contour.
D D. The Purbeck Hill; maximum elevation 654 feet, just behind Creechbarrow.
E. Blackhills Plantation, about the 300 feet contour.
F. Spoil-heaps of the clay workings.

North-East Side of Creechbarrow: Additional Particulars as to the Creechbarrow Beds.—From the above figure the *topographical* relations of the Creechbarrow Beds to the Pipeclay series can be seen at a glance; the former looks down upon the latter. It is

[1] No. 1 appeared in the June number of the Geological Magazine for 1902. It was then intimated that the subject would be treated more fully in the Proceedings of the Dorset Field Club. This has been done, and a portion of the additional matter is now, by the kind permission of the Publication Committee of the Dorset Field Club, reproduced in the Geological Magazine. This portion relates mainly to the lithology and palæontology of the Creechbarrow Beds.—W. H. H.

Plate XI, illustrating this paper, will appear in the May number with the remaining part of the article.—Edit. Geol. Mag.

scarcely necessary to point out that the Purbeck Hill (D D), consisting of Chalk, is depressed by perspective, the highest part of it slightly exceeding the height of Creechbarrow. A word as to the composition of the Creechbarrow Beds seen in this figure may be useful as a sort of recapitulation of what has already been stated. If I give this in the form of a generalized vertical section, it is merely for the sake of convenience, and not to be regarded as absolutely true at any one point.

1. The highest bed of the series is the deposit on the Creechbarrow Limestone. With this must be associated the beds above the 'marl' detailed in the northern section. The thickness of these latter beds is about 13 feet down to the 'main marl,' and they consist of sands, clays, flints, and a thin bed of 'marl.'

2. The next in downward succession is the hilltop, or Creechbarrow Limestone, which is excessively hard at the summit (A), but becomes softer when traced on the dip slope towards the 500 feet contour (the letter C is approximate); in this condition it is known as 'marl,' and may be about 12 feet thick in some places.

3. The beds immediately *below* the Creechbarrow Limestone are extremely variable, and constitute a stratigraphical crux of considerable perplexity. They certainly differ materially within short distances, and but little analogy can be traced between those on the south side of the summit and those on the north side, which are below the 500 feet contour. On the south side of the summit these beds have been traced in detail with considerable accuracy for about 20 feet vertical, and this must be regarded as the standard section.

On the whole, we may sum up by stating that the beds immediately below the summit Limestone, for a vertical extent of perhaps 30 feet or more, are sandy, with some yellow clay, frequently manganiferous, and are characterized by numerous beds of flints, the beds ranging from 6 inches to 3 feet 6 inches in thickness; loose flints also occur in the sands.

In further illustration of this class of beds I would direct attention to the eastern spur of Creechbarrow (B of Fig. 1). This spur is a conspicuous object from the north-east side, since it breaks the regularity of the conical outline as seen from Furzebrook.

Being desirous of finding some evidence as to the cause of this slight local prominence, I had a special pit sunk on the very top of it, with the following result:—

Pit on the eastern spur of Creechbarrow.	ft.	in.
a. Sandy earth with flints	0	6
b. Flint-gravel	3	6
c. Buff, ferruginous sand with manganese nodules	2	6
Total section	6	6

The flint-gravel (*b*) of this section is the thickest deposit of the peculiar 'gravel' of Tertiary age as yet discovered on Creechbarrow; water was lying in the bottom of the pit, apparently due to a pan formed by surface action. The extent of the opening scarcely

permitted us to ascertain whether there is any bedding in the 'gravel.' The stones are of very unequal size, varying from flints 30 lb. in weight to quite small stones; I did not at the time notice any pebbles. The character of the flints here is just the same as in all the Creechbarrow Beds; the large ones have a partially rounded exterior consisting of white silica thoroughly degelatinized. Some are degelatinized throughout, others have a brown core of gelatinous silica still left; most of them are very brittle and fly to pieces on being struck by the hammer. At present it is not possible to connect this particular bed of flints with those found in the pits near the summit. That there are beds of flints occurring in stratigraphical relation to the sands and clays of this hill is certain, and they probably occur on several horizons. The manganese nodules in the buff, ferruginous sand are very interesting and fairly abundant. I shall refer to them again when dealing with the lithology of the Creechbarrow Beds.

The evidence obtained in this pit on the eastern spur goes to confirm the supposition that the abundance of bedded flints of Tertiary age in the upper part of Creechbarrow has materially assisted the limestone in preserving the softer sands and clays from denudation. Such an observation may be accepted as a general one, applicable more or less to the whole hill. When we come to particulars the limestone is more especially accountable for the summit (A), whilst the unusual accumulation of flint 'gravel' is more directly the cause of the eastern spur (B).

3′. *The Buff-coloured Clay.*—Still dealing with the deposits immediately below the limestone and 'marl,' we have seen that, on the northern slope and some distance below the 500 feet contour, the calcareous series rest on a few feet of sands with flint-gravel, and that below this comes a very important deposit of buff-coloured clay (Mr. Bond's clay-pit), which may occur as a lenticular mass, as it does not appear to have any representative if followed in the direction of the eastern spur.

4. The lowest member of what I have termed the Creechbarrow Beds are the 'Sands' underlying the buff-coloured clay. These can be studied at Mr. Bond's sandpit, where the following section may be noted:—

CREECH SANDPIT.

	ft.	in.
a. Clay with rootlets	1	6
b. Clay passing into sands; flints occur, especially towards the base (? unconformity)	5	6
c. Bedded sand	1	3
d. Yellow clay with large flints at base and a pink line ...	1	0
e. Yellow variegated sandy clay with a few small flints ...	1	6
f. Salmon-coloured sand with a black centre line, the coloration probably due to manganese	0	3
g. Very fine white sand with but little true bedding (not bottomed)	9	0
	20	0

N.B.—*a* and *b* represent the base of the Creech brickearth or buff clay.

This concludes the description of the Creechbarrow Beds as far as I have been able at present to trace them. If we turn to Fig. 1 we perceive that the convenient obscurity afforded by the Blackhills Plantation helps to conceal their possible relation to the Pipeclay series; all we can say is that, topographically speaking, they occupy the higher ground, and that when we get well below the 300 feet contour the Pipeclay series has possession of the surface.

Lithology and Palæontology.

The big Flints.—Before entering upon a detailed description of the Creechbarrow Limestone, there are some other matters of interest which may be considered. The first of these refers to the very large flints which have contributed in no small degree to the maintenance of the fabric of Creechbarrow, and which are such an exceptional feature in the Bagshot beds of this immediate district: their stratigraphical relations may be gathered from the preceding pages. As

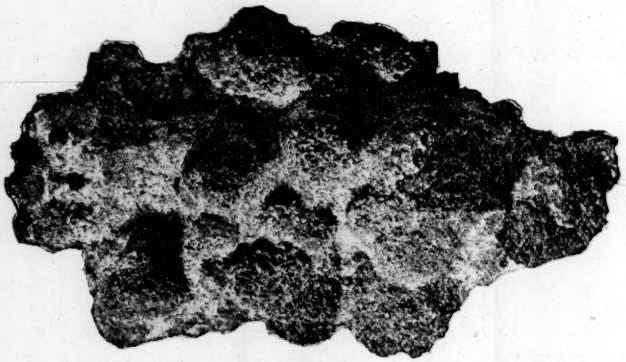

Fig. 2.—One of the manganese nodules from the eastern spur of Creechbarrow. Reduced $\frac{2}{3}$ (from a photograph).

regards the general character and appearance of these flints, they are for the most part of a dirty cream-colour; they are also much degelatinized, and in some cases the exterior is simply a mass of granular silica, very meagre to the touch. They are also extremely brittle when first dug out, though it is probable that exposure to the atmosphere toughens them after a while. In consequence of this brittleness the available fragments do not much exceed 28 lb. in weight, so far as I have seen them, though it may well be that heavier flints than these occur. These flints have split in the bed itself. The surface of those flints which are not much broken has been subject to very little modification from abrasion. Associated with the big flints are flint pebbles and other stones of moderate size, also quartzose grit.

The peculiar fawn colour of these siliceous masses will help to distinguish them from ordinary plateau-gravel or valley-gravel

flints; and the amount of soft and almost pulverulent material which coats so many of them is a further distinction, as this substance could never endure the wear and tear of the gravel-making processes. Without illustration, which would necessitate the employment of colour, it is by no means easy to convey an adequate idea of the peculiarities of the big flints, when freshly dug out of the beds which contain them. Their general appearance leads one to suppose that they had been subject to some corrosive action, and this is especially noticeable where there are any indications which may have been due to organic bodies, such as urchins or sponges.

When these Creechbarrow flints have been rolled down the hillside, and subjected to atmospheric action, the external coating of loose silica is found to have been entirely removed, and the flint itself bleached to a dirty white condition, though the casts of Pectens and other fossils still retain traces of iron-discoloration.

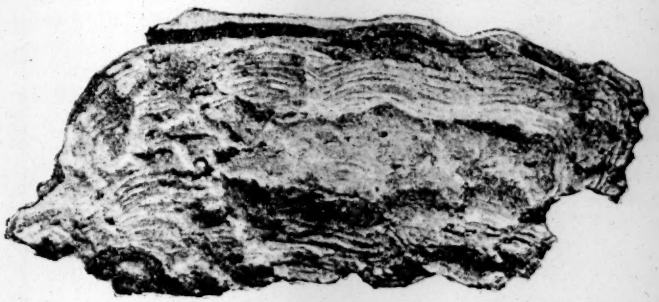

Fig. 3.—Part of a calcareous nodule from No. 4 pit. Nat. size.

The Manganese Nodules.—There are considerable traces of black oxide of manganese both in the clays and limestones of Creechbarrow, but the remarkable nodules which I am about to describe have only been found in the yellow sand underlying the great flint bed on the eastern spur (see p. 152). Here the most beautiful botryoidal masses of this black oxide, which is probably the hydrated peroxide, or psilomelane, are common and of great variety in form. The one figured has a length of five inches, and its specific gravity considerably exceeds that of the manganese nodules which are figured in the description of the voyage of the "Challenger."[1] In other respects there is a general resemblance, the chief difference being that in our case ordinary quartzose sand functions as the material caught up by the mineral instead of fine pumice and volcanic fragments, etc., as in the case of those found at the bottom of the Pacific. I have not seen any nodules from the Pacific where the mamillæ are so salient or so rough as those from the east spur of Creechbarrow, which are handsomer in shape, heavier, and present

[1] Deep Sea Deposits, pl. ii.

greater contrast of colours. It is evident that great depth is not absolutely necessary to the formation of manganese nodules, as the Creechbarrow Beds, being associated with fresh-water limestone, could not be other than shallow-water deposits, whilst the manganese nodules from the bottom of the Pacific Ocean were formed in depths between 2,500 and 3,000 fathoms.

The Creechbarrow Limestone. — Perhaps the first stage in the description of this curious rock should be an illustration of the mode of its growth in the associated sands. This may be well studied in No. 4 pit, where there were several calcareous nodules just underneath the irregular base of the great mass of limestone. The one figured (Fig. 3, p. 153) may be deemed characteristic.

Externally there is a kind of skin made up of very closely set calcitic layers, which have a rough exterior and include a few sand grains. The rest of the nodule consists mainly of carbonate of lime with a small amount of very fine mechanical sediment. In this respect it differs greatly from the manganese nodules, which take up a large quantity of the sandy matrix. The concentric character of this concretionary body is well shown towards the exterior, and occasionally in the interior, but the general mass is a rather light porous material with denser nests of calcitic matter here and there. Some of the holes in the more porous parts are suggestive of slender stems round which deposition in the first instance has taken place, and the aspect generally may be described as tufaceous.

(*To be concluded in the May Number.*)

III.—The Composition of Indian Laterite.

By H. Warth, D.Sc. Tübingen, and F. J. Warth, B.Sc. Lond. and Birmingham.

AFTER the appearance of Mr. T. H. Holland's paper on Laterite in the Geological Magazine, February number (pp. 59–69), we can at once give the results of our analysis of Indian laterite, without further introductory remarks. They are as follows :—

I. *Pure Gibbsite from Kodikanal, previously recorded in the Mineralogical Magazine, May,* 1902.

H_2O	33·74
SiO_2	2·78
TiO_2	·04
CaO	·20
MgO	·03
Fe_2O_3	·44
Al_2O_3	62·80
	100·03

Molecules of water for one molecule of alumina = 3·06, which agrees very closely with the formula of gibbsite, $Al_2O_3 + 3H_2O$. Specific gravity = 2·42.

II. *Composition of four Bauxites very rich in alumina, and containing little iron, closely resembling the variety called 'Wocheinite.'*

	2 Kh.	3 Pl.	4 Sr.	5 Rw.
H_2O	26·47	24·00	28·10	26·94
SiO_2	·93	1·79	2·01	2·35
TiO_2	1·04	3·30	6·49	6·61
CaO	·36	·04	·45	·15
MgO	—	·02	—	*nil*
Fe_2O_3	4·09	6·21	5·48	6·53
Al_2O_3	67·88	64·64	58·23	57·50
	100·77	100·00	100·76	100·08
Molecules of water for one molecule of alumina:	2·23	2·11	2·75	2·67

If we take the mean of these figures and calculate the proportion of gibbsite and diaspore ($Al_2O_3H_2O$) in the mixture, we find 72 per cent. gibbsite and 28 per cent. diaspore. As the proportions vary from 55 per cent. to 88 per cent. gibbsite, we may roughly say that these rich bauxites or 'wocheinites' consist of about three-fourths gibbsite and one-fourth diaspore. Specific gravities: No. 3 = 2·59; No. 5 = 2·39.

III. *Composition of 8 specimens of Laterites in sitû which are Bauxites.*

	6 Marwara.	7 Mahab.	8 Satara.	9 Nilgiris.	10 Nilgiris.	11 Pulsa.	12 Karad.	13 Satara.
H_2O	26·82	24·99	23·88	20·70	19·00	15·87	11·82	14·39
Quartz, SiO_2	—	—	—	—	10·52	—	1·77	—
SiO_2	3·90	·72	·37	3·14	·23	3·56	4·20	·90
TiO_2	·38	·42	4·45	—	·10	·13	·10	1·59
CaO	·35	·00	·86	—	·40	·52	*nil*	·64
MgO	—	—	—	—	—	trace	trace	·20
Fe_2O_3	13·75	23·41	26·61	37·88	34·37	47·27	51·25	56·01
Al_2O_3	54·80	50·46	43·83	38·28	35·38	32·65	30·86	26·27
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Molecules of water for one molecule of alumina:	2·80	2·83	3·11	3·09	3·07	2·77	2·19	3·13

Average of the above = 2·87, which implies 93·5 per cent. gibbsite to 6·5 per cent. diaspore, with variation from full gibbsite to 60 per cent. gibbsite.

These bauxites in blocks and in powder are generally red with a shade of brown; No. 9 is light brown, Nos. 12 and 13 are of a deep red.

IV. *Composition of ten detrital Laterites.*

	14	15	16	17	18	19	20	21	22	23
Locality	Belgaum District.			Jabalpur.	Dharwar.	Balaghat.	Birbhum.	Madras Neighbourhood.		
Colour when pulverized ...	lavender.	red.	brown. red.	red.	redd. brown.	brown.	redd. brown.	redd. brown.	brown.	ochre.
H_2O	13·31	11·42	11·61	10·93	9·64	7·73	9·60	8·66	8·40	10·74
Free quartz, SiO_2	32·24	6·67	8·93	4·53	16·65	39·53	6·29	28·04	32·46	24·39
Combined SiO_2	9·94	13·35	16·69	23·32	14·79	7·96	17·49	14·07	13·33	10·42
TiO_2	·04	·25	·10	·43	·02	·01	·04	·01	·01	·01
CaO	·00	*nil*	·00	*nil*	·04	—	·03	*nil*	·06	·38
MgO	*nil*	*nil*	*nil*	*nil*	trace	—	*nil*	—	—	trace
Fe_2O_3	8·77	41·50	35·69	28·99	35·81	28·38	42·33	30·51	35·34	47·39
Al_2O_3	35·70	26·81	26·98	31·80	23·05	16·39	24·22	18·60	9·93	6·67
Total ...	100·00	100·00	100·00	100·00	100·00	100·00	100·00	99·89	99·53	100·00

The same, with the clay calculated separately from the combined silica (Kaolin = $Al_2Si_2O_7 + 2H_2O$) :—

Free quartz, SiO_2	32·24	6·67	8·93	4·53	16·65	39·53	6·29	28·07	32·61	24·39
Clay as Kaolin, $Al_2Si_2H_4O_9$	21·42	28·77	35·97	50·26	31·88	17·16	37·69	30·33	(27·39)	(20·22)
Balance identical with Bauxite. H_2O ...	10·33	7·41	6·60	3·93	5·20	5·34	4·35	4·45	4·42	7·61
TiO_2 ...	·04	·25	·10	·43	·02	·01	·04	·01	·01	·01
CaO ...	·00	*nil*	·00	*nil*	·04	—	·03	*nil*	·06	·38
MgO ...	*nil*	*nil*	*nil*	*nil*	trace	—	*nil*	—	—	trace
Fe_2O_3 ...	8·77	41·50	35·69	28·99	35·81	28·38	42·33	30·55	35·51	47·39
Al_2O_3 ...	27·20	15·40	12·71	11·86	10·40	9·58	9·27	6·59	—	—
Total ...	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

The above specimens of Indian laterite are arranged in order of their contents of free alumina, with the exception of the first, the pure gibbsite, which, however, is the richest in alumina if the water is eliminated. The specimens range from 68 per cent. of free alumina down to nothing. There is thus every gradation in alumina from nearly theoretically strongest downwards, with no gap to speak of. If, however, we take into consideration the other constituents we find the specimens to fall into four distinct groups.

I. By itself stands the gibbsite from Kodikanal, which is so much free of foreign matter that in the ignited state it contains nearly 95 per cent. of aluminium oxide. As stated in the notice in the Mineralogical Magazine, this mineral was found to form a deposit of one foot in thickness, consisting of loose crusts or plates which gave the impression of having been extracted from the underlying charnockite. The sp. gr. of this gibbsite was 2·42.

We next come to specimens of the far more extensive and thick-bedded surface deposits, which have hitherto all been classed under the name 'laterite.'

II. Of these laterites the first four specimens belong to our second group. They agree, as already stated, very well with those richest bauxites which have been given the separate name 'wocheinite.' They are characterized by their small amount of iron, and have even less silica than the recorded analysis of the celebrated original wocheinite, on an average 1·77 per cent. compared with 6·29 per cent. at Wochein. On the other hand they contain much more titanium-dioxide. This large proportion of titanium-dioxide (maximum 6·61 per cent.) is very characteristic of the rich bauxites, and a reference to the whole of the tables will show that the titanium-dioxide gradually decreases with the free alumina until there is only ·01 per cent. left. It remains a subject for further enquiry in what form the titanium exists when there is such a large proportion. From the fact of its dissolving when the entire mineral is treated with hot hydrochloric acid, and because there is always enough iron present, we are inclined to believe that it exists chiefly as ilmenite. As already mentioned, the specimens of this group are mixtures of about three-fourths gibbsite and one-fourth diaspore (by weight). The mean specific gravity of two specimens was 2·49, which is more than that of the Kodikanal gibbsite. Our specimens have also the characteristic pisolitic structure, the globules varying from two to four millimetres in diameter.

III. The third group includes specimens such as geologists have hitherto called high-level laterites. They are bauxites which have formed from highly ferruginous igneous rocks. They belong mostly to the area of the Deccan trap, and we find that the proportion of ferric oxide in these bauxites is in close relation to the proportion of iron in the trap. In the same way the small proportion of iron in the preceding group of wocheinites indicates their origin from less ferruginous, probably gneissic rocks. A glance at the table, group III, also shows the regularity with which the water decreases

in the same order as the alumina, whilst the iron increases simultaneously.

Only in one case, that of No. 13, is there a slight departure from the rule. With the exception of two specimens containing quartz-sand, the quantity of silica is very small. Sample No. 7 contains only 1·14 per cent. of substances other than the oxides of iron and aluminium besides water. The ferric oxide appears to be entirely or nearly entirely anhydrous. If this were not the case we should obtain a regularly increasing series for the molecules of water calculated from the total of the water for one molecule of alumina. Although the table shows that the figures vary, there is no great departure from the average, and, as already remarked, the mean of all the eight specimens implies anhydrous ferric oxide and a mixture of 93·5 per cent. gibbsite and 6·5 per cent. diaspore.

The identity of these high-level laterites with bauxite is also proved by comparison of their composition with that of other bauxites. Our No. 7 is almost identical with the bauxite from near Giessen with which Dr. Max Bauer compared the specimen from Mahé in the Seychelles.

Our specimen No. 9 comes very close to an Irish bauxite which has been analysed by Siemens, who found the following, according to Watts' Dictionary of Chemistry :—

H_2O	21·5
SiO_2	3·5
TiO_2	2·0
Fe_2O_3	38·0
Al_2O_3	35·0
	100·0

Treated before the blowpipe, all the specimens of group No. III are infusible, the general character of bauxite. Only in the case of No. 10 there were minute fused spots in small number, and No. 12 showed also traces of fusion, though they were doubtful. This behaviour of No. 10 and No. 12 is no doubt due to these specimens containing more silica than the others and free quartz-grains. This infusibility serves to distinguish the pure bauxites when mixed with Fe_2O_3 from the low-level laterites of the following group, No. IV, which (No. 14 excepted) fused unmistakably. Pure kaolins are also infusible, but if the material is distinctly red from iron the test holds good.

IV. The fourth group includes low-level laterites arranged in order of free alumina which calculation shows them to contain. The presence of free silica in the form of quartz is proved in all cases, and confirms a principal character of these deposits. Whenever distinct quartz-grains are seen in quantity, some of them being at times rather large, we may be sure that we have a detrital or low-level laterite. Besides the quartz-sand there is, however, generally an even larger proportion of clay.[1] This follows from the

[1] On the average 30 per cent. of clay and 20 per cent. of free quartz.

proportion of combined silica which is present, and which we may fairly assume to be a constituent of clay. In the table the amount of clay is calculated according to the composition of pure kaolin (kaolin equals SiO_2 46·4 per cent., Al_2O_3 39·7 per cent., H_2O 13·9 per cent.). The balance which is left after deducting both free quartz and clay consists of free alumina and ferric oxide with water. This is really the substance of bauxite, with gradually decreasing proportion of alumina. The results of the analysis agree thus remarkably well with the theory according to which the low-level laterite is derived from the high-level laterite, and has during its transport to a new site taken up sand and clay as impurities. Further, the results show that the term laterite has a distinct meaning throughout the many varieties of this rock. Laterite is bauxite in various degrees of purity, from the richest wocheinite down to such specimens in which the free alumina has entirely disappeared. In this sense the specimen from Burmah which has been analysed by Captain James, and recorded in the Manual of the Geological Survey of India, is also still a true laterite. Its composition is similar to that of our two last specimens, No. 22 and No. 23. The sample contained 30·7 per cent. quartz and 14·8 per cent. clay, and the balance was made up almost completely of ferric oxide (47·4 per cent.) with 4·7 per cent. water and only 1·3 per cent. free alumina.

It cannot be said with certainty what the state of hydration of the alumina is in these detrital laterites. They vary so much in composition, and the colours indicate that the ferric oxide may in some cases be anhydrous and in other cases be present as limonite. Taking all the specimens together, the average composition is such that there is about as much diaspore as there is gibbsite and about as much hematite as there is limonite.

As regards the method of analysis, we found fusion with hydrogen sodium-sulphate the best, if not the only method for all cases. By it the free silica is readily determined as distinct from the combined silica, the iron is obtained in solution, and so is the titanium. With larger proportions of titanium (1 per cent. TiO_2 and upwards) we resorted to the method of separation by long-continued boiling, and small proportions of TiO_2 were determined colorimetrically by means of hydrogen peroxide.

To carry out this work at a distance from India would have been impossible, had we not received very liberal help in procuring specimens from a deposit which extends over an area of thousands of square miles. We desire to express our thanks to H.M. Secretary of State for India, through whose kind intervention the bulk of the very richest and most important specimens came into our hands; also to Mr. Edgar Thurston of Madras and to Dr. D. Hooper of Calcutta, who obtained for us the specimens by which the true nature of the high-level laterite was proved for the first time.

REVIEWS.

I.—Volcanic Studies in Many Lands; being reproductions of photographs, by the Author, of above one hundred actual objects, with explanatory notices. By Tempest Anderson, M.D., B.Sc. Lond., F.G.S., F.R.G.S., Fellow of University College, London, Hon. Sec. Yorkshire Phil. Soc. 4to; 202 pages, 105 plates. (London: John Murray, Albemarle Street, 1903.)

PHOTOGRAPHY has become, to a certain extent, the handmaid of Science, and Geology especially is indebted to this delightful art for many a faithful picture. The glacialists have long availed themselves of this method of delineation, whilst the British Association has shown its appreciation of the value of photography in its application to geology by the appointment of a committee to arrange for the collection, preservation, and systematic registration of photographs of geological interest in the United Kingdom. Since 1889, when it was first constituted, this committee has collected several thousand photographs, many of which are of the highest value, and a selection from these is now in course of publication.

It is not surprising, therefore, that Dr. Tempest Anderson, having already acquired considerable skill in the art of photography, and being, moreover, of a scientific turn of mind, should have chosen to illustrate volcanic phenomena with the camera, as a method of spending a physician's holiday at once useful and agreeable. Vulcanology was more especially selected, as it had the advantage of giving opportunities for exercise in the open air and frequently in districts remote and picturesque. For the last eighteen years the author has spent the greater part of his holidays in this fashion. During that period, Vesuvius, Etna, the Lipari Islands, Auvergne, the Eifel, the Canaries, Iceland, British extinct volcanic regions, and many localities on the western side of the North American continent were visited. In delineating those phenomena he has chosen the mechanical side of the subject, "the mode of formation of volcanic cones and lava-streams: how the materials forming them got to their present position, and remained there rather than elsewhere: how they have affected the other rocks with which they came in contact, baking and hardening some, dissolving and removing others; in some cases by their superior hardness protecting the rocks over which they have been deposited, while the surrounding parts have been removed by denudation, so that what was once a molten stream on the floor of a valley is now a bed of hard, perhaps columnar, lava, capping a long hilltop, while in other cases the volcanic beds themselves have suffered most from denudation; how veins and intrusive sills are sometimes harder than the rocks they traverse, and weather out into 'Giant Walls,' but in others are softer, and become gullies and the beds of streams."

The author has long been known as a demonstrator in vulcanology, having commenced his public career before the British Association at Aberdeen in 1885, when he read an illustrated paper on the Volcanoes of the Auvergne. At the Bath Meeting in 1888 he read

a similarly illustrated paper on the Volcanoes of the Two Sicilies. He has also been in the habit of exhibiting at the soirées of the Royal Society, and these exhibitions were systematized into four lectures (the Tyndall lectures) delivered at the Royal Institution. It is scarcely to be wondered at that, with such a record, Dr. Anderson was appointed a member of the commission sent out last Summer by the Royal Society to investigate the results of the eruptions in the Windward Islands. Oddly enough, he was on the point of bringing out the present work when this journey was commenced, so that the delay has enabled him to introduce a few of his West Indian photographs.

The first seventeen plates of the work, together with their explanatory text, are devoted to Vesuvius and its vicinity, and in this connection the eruption of 1898 occupies an important place. The character of these lavas is strikingly exemplified, especially where the picture is taken at close quarters, showing a *coulée* of lava of the corded type (a slaggy lava). This stream is small and narrow, whilst some of the loose blocks around approach the cindery or scoriaceous type of lava. For comparison there is a photograph of blast furnace slag from Seaton Carew. Here we perceive the effects of a tip of molten slag down a spoil-bank, thus producing a flow of artificial corded lava marvellously like the natural product. These two types of structure, viz. the corded (slaggy) and the cindery (scoriaceous), are mainly dependent on the amount of aqueous vapour, which, if excessive, renders the cooling stone vesicular, so that a lava-stream may be slaggy in one part and cindery in another.

Next we are presented with the actual phenomena of eruption as noticed in the middle of September, 1898. One of these pictures shows the moving of lava on the steep slope in the act of solidifying as a cascade of stones, in this case of the scoriaceous type. The picture is so graphic that we might almost fancy we heard the rattling. Then we are shown a part of the crater, as it existed during a phase of the same eruption—a vast pit probably a quarter of a mile in diameter, with almost vertical sides, the actual depth being obscured by the vapours issuing therefrom : the quaquaversal inclination of the strata of lava and tuff is well brought out. Showers of red-hot stones were coming out of the bottom of the pit, but the author was fortunate perhaps in not being able to photograph any of these. Finally, we have in pl. x a picture of the explosion, which occurred two days afterwards, as seen from the Observatory, the magnificent cloud of vapour and ashes being intensified by the slanting rays of the sun.

These photographs of the phenomena of eruption more especially appeal to the vulcanologist, but there are others likewise of great geological interest. Ever since the days of Lyell the Phlegræan Fields have been classic ground for all those who seek to interpret the past through the action of the present. There is probably no more exquisite example of a crater, presumed to be extinct, than that of Astroni (pl. xiii), whose picturesque and wooded interior affords such a telling section of consolidated volcanic ash dipping

away from the centre of the cavity. As a mere artistic study this picture is specially worthy of commendation. Well-defined extinct craters are by no means rare in the world; there are plenty in the Auvergne. Yet in some cases the interest is enhanced by their enclosing a lake, such as the Pulvermaar in the Eifel or the Lac d'Issarlès in Central France. But the queen of crater lakes is to be found in the Cascade Range of Oregon (pl. lxxxiii). This, again, is a most telling picture, though the outward dip of the beds is not so obvious, owing partly to a considerable accumulation of talus. The dimensions are very great, as the following statement will show:—"An explosive eruption of enormous magnitude has removed several thousand feet of the summit and distributed the material over the surrounding country. The result is a crater about 8 miles by 6 in size, the rim of which reaches a height of about 8,000 feet above the sea. The cliffs rise about 2,000 feet above the surface of the lake, which is in places 2,000 feet deep." An island in this marvellous lake shows a crater within a crater, and had this been still larger it would have been comparable, he observes, to the Peak of Teneriffe, which is surrounded by an old crater-ring of about the same size.

It will scarcely be necessary for us to follow the author through the Lipari Islands and the Canaries, in both of which groups most interesting volcanic phenomena are faithfully delineated by his camera. But the extinct volcanic region of Central France calls for special attention on the part of geologists, and to this region about a dozen plates are devoted. The first of these plates (No. xxviii) is a remarkable piece of topography, being a sort of general view of the chain of the Puys, looking south from near the summit of the Puy de Dôme. Notwithstanding the difficulties of dealing with such an extended landscape, the outlines are clear even to the most distant hills, and the effective side screen of domite in the foreground, besides reminding us of that peculiar rock, gives an artistic touch to the entire composition. The companion picture, looking north, if less artistic, is even more important from a topographical point of view, as we almost look down into the crater of the Puy de Pariou, while the positions of the Grand Sarcoui, the Puy Chopine, and other noteworthy puys are indicated with great distinctness. In the succeeding plates we are introduced to the Puy Chopine and Grand Sarcoui at close quarters. The peculiar elongated dome shape of the latter is well brought out, and it is possible to believe that it was extravasated as a pasty mass in the position it now occupies between two scoria-cones on either side of it.

Having dealt with the phenomena of the acid rocks in Central France, Dr. Anderson presents us with some very striking pictures of the effects of basalt in that region, and he has in many cases selected basalt necks for illustration. In some instances these necks, by resisting denudation, have given rise to most singular isolated pinnacles of rock, often crowned with a building like the Rocher de St. Michel. In this case he considers that the material forming the pinnacle originally accumulated in a volcanic chimney as an agglomerate; the scoria-cone, which once probably surrounded or

crowned the whole, has been denuded away, and the more durable rock, forming the neck, alone remains.

The delineation of columnar structure in basalt has received great attention from Dr. Anderson, and his efforts in this connection have been very successful. Central France, the coast of Antrim, and the Eifel are amongst the regions which he has specially selected. Let us take, for instance, the "Valley of Jaujac in the Ardèche" (pl. xxxviii). The subject has attracted the notice of many a geologist, and our readers may remember that the "volcanic cone and basaltic lava-current of Jaujac" constitutes the frontispiece of the second edition (1858) of Scrope's "Volcanoes of Central France." Our author's photograph deals with a limited portion of Scrope's original picture. Pl. xxxviii, in our opinion, serves to illustrate the character of this work on volcanic studies, where a landscape of extreme interest and beauty is also rendered most instructive as a geological section, showing columnar basalt at the bend of the river. There seem to be two beds, totalling 150 feet vertical, but the author regards these as the result of one lava-stream, "the appearance of division being produced by the line of junction of the columns of which both portions are composed, and which owe their origin to cracks due to contraction by cooling of the upper and lower surfaces respectively, and their extension inwards until they meet."

Whilst dealing with the subject of columnar basalt attention may be directed to remarkable examples in the Eifel district (pls. lxxviii, lxxix*a*, and lxxx). The Käsekellar is a noted instance, where the basalt is massive above and sub-columnar below, breaking up into short joints like Dutch cheeses, whence the name. Equally remarkable in a different way is the structure of the Hummelsberg, showing a system of fine vertical columnar jointing, which almost reminds one of fibrous serpentine (chrysotile) on a large scale; whilst the disposition of the basaltic column in the Mindenberg is held to be an example of cooling from the top; the structure is very peculiar. There are also two very effective pictures (small) of the Giant's Causeway, whilst the relations of the basalt to the Chalk on the coast of Antrim are fully depicted and their historical significance dealt with in the text.

There remains one very extensive subject, viz. Iceland, to which thirty plates are devoted. To do anything like justice to this part of the work would almost require a separate notice. Dr. Thoroddsen has animadverted lately in very severe terms on the majority of modern works on Iceland, as consisting largely of personal details. Nothing of the sort can be alleged against Dr. Anderson. He appears to have spent two Summers there, and his photographs tell their own story of this treeless land of frost and fire, with occasional assistance by way of interpretation in the text. It is a triumph of the positive method as against the flood of speculation with which geological literature is occasionally inundated.

The Hafragil's Foss in the valley of the Jökulsá (pl. xlix) is a fine specimen of terrace cutting through horizontal volcanics of an older series. This river may be regarded as typical of Iceland, since

it rises beneath the ice-sheet of the Vatna Jokul, and after running through the terrible waste of the Myvatn's Örœfi, finally discharges as a regular glacier river into the Asar Fjord on the north. In pl. L, a more specialized section is given, where the same river is seen plunging into a cañon about 400 feet deep, cut in the columnar basalt. The author again points out that the separate layers observed here need not in all cases represent a different eruption, and he refers to his remarks on the Jaujac section (pl. xxxviii) as applicable in this case. At the northern end of the Jökulsá gorge some remarkable volcanic structures are exhibited as the result of the injection of basaltic lava into volcanic ash (pls. lii and liii).

One other subject in connection with the copious illustration of Icelandic phenomena must suffice—we refer to the fissures termed Gjás, due to the unequal settlement of the lava-crusts on cooling. These seem well developed in the Reykjanes peninsula, and are partly due to the formation of tunnels, whereby the still liquid lava continues to flow after the surface has consolidated. The mouth of one of these old tunnels is shown as a lava-cava at Myvatn (pl. lxxii). The celebrated Almannagjá in the valley of the Öxerá is an instance of a Gjá (pl. lviii), and this has all the appearance of a road hollowed out between a cliff and its undercliff. But the most interesting series of Gjás, from an historic point of view, are those which surround the Logberg, on which the Icelandic Parliament met at Thingvalla. The half-plate, No. lxi, shows us this curious rock table, held up in a fork between two faults and almost surrounded by deep Gjás, full of water, fresh, clean, and running — a nice place to cool the ardour of an obstreperous legislator!

There are many interesting photographs from well-known volcanic regions on the west side of the North American continent; and the author, as we have already noted, has just had time to add five very graphic pictures of the recent West Indian eruptions. We trust, however, that we have already indicated sufficient to give a general idea of the work, which has been a labour of love, occupying the author's spare time for the last eighteen years. In this work art and science are happily combined, so that our æsthetic tastes are gratified, whilst we are receiving instruction in the mechanism of volcanic action, past and present. May we not say that the author and photographer has realized the *Omne tulit punctum qui miscuit utile dulci* of the Latin poet?

Whilst expressing our admiration of this work we must draw attention to a passage on page x of the preface, where the author states "that the mere enumeration of books and papers on Vesuvius and the other South Italian volcanoes occupies 340 *quarto pages* of a Report of the Geologists' Association." Apart from the inherent improbability of a mere list of the literature of the subject occupying 340 quarto pages, we are in a position to state that the present librarian of the Geologists' Association knows nothing of any such report.

W. H. H.

II.—Mineralogy: an Introduction to the Scientific Study of Minerals. By Henry A. Miers, D.Sc., M.A., F.R.S., Professor of Mineralogy in the University of Oxford. pp. xviii and 584, with two coloured plates and 716 illustrations in the text. (London: Macmillan & Co., 1902. Price 25*s.* net.)

HITHERTO, when asked to recommend a textbook on mineralogy, one has been at a loss to name a book suited to the needs of the student or serious general reader. With the appearance of Professor Miers' long-promised work, this difficulty vanishes, and the book may be unhesitatingly recommended as a really *readable* work, setting forth the principles of scientific mineralogy, and not unduly burdened with facts and technical details. Most of the textbooks hitherto attempted are little more than catalogues of the characters (often imperfectly determined) of mineral species, and of the localities, more or less uninteresting, where they are found. Much of this tedious detail, only in place in larger works of reference, has been omitted in the present book; Professor Miers has clothed the dry bones of mineralogy and produced a work full of life and interest. Had such an introduction to the study of mineralogy appeared years ago, there can be little doubt but that the science would be a more popular study than it now is in this country.

One of the most striking features of the book is its wealth of illustration. The numerous figures, all original be it noted, are in every way excellent; indeed, it would be possible to gain a very good idea of the subject by simply studying the figures and the lucid explanations with which they are accompanied. The representation of minerals as they actually occur in nature, in addition to idealized outline drawings of crystals, has been attempted in but few works on mineralogy, and, as far as we know, in no English textbook hitherto published. Many of these in the present work have been reproduced directly from actual specimens by photographic processes. Photographic reproduction, however, frequently fails to bring out the relation between the planes and edges of the crystals represented; this difficulty has been overcome in the present work by reproducing artistic black and white drawings of actual specimens, the characteristic features of which are brought into special prominence. The lines representing the edges of the crystals in many of these figures might with advantage be a little less heavy, but otherwise they are altogether excellent. In addition to the figures in the text are two coloured plates, the one representing an interference figure as seen in monochromatic light and the other the same figure seen in white light. Reproduced directly by photography and three-colour printing, these figures are probably the first of their kind to appear in textbook illustration.

The subject-matter of the book is divided into two parts of about the same length, each of which presents several novelties of treatment. Part I deals with the essential properties of minerals, and Part II consists of a description of the more important mineral species. The first chapter of the book, treating of geometrical crystallography, will give the beginner a clear idea of the symmetry

and form of crystals; it does not pretend to be exhaustive, and the mathematical relations, though clearly and briefly set forth, are not brought into prominence, nor are any detailed examples given in the methods of calculating crystals. About half (38 pages) of this chapter is occupied by a description of the different crystal-systems; 22 of the 32 classes are described, all those, that is to say, which are unquestionably represented among minerals. A complete list is given in an appendix at the end of Part I. The names employed in Dana's textbook for the crystal-classes (e.g., calcite class, cuprite class, etc.) have been wisely adopted in place of the unnecessarily long and confusing names (different in every author) which one finds elsewhere.

In the appendix on the crystal-classes, names of the latter type are employed, and like other authors, the present one has not refrained from inventing new terms to denote the different types of symmetry, some of which (e.g., alternating, equatorial, central) seem desirable innovations. This lack of uniformity in nomenclature is doubtless unavoidable in a science which has not been standing still, but it is none the less much to be deprecated. In this connection we may remark that, according to the preface, Dana's mineral names have been adopted; in the text, however, are to be found fluor, pyrites, blende, anatase, copper-glance, mispickel and other names not used by Dana.

In the portion on geometrical crystallography there are short, but useful, chapters on vicinal faces and light figures, and on etched figures, the relation of which to the symmetry of the crystal is specially pointed out. In the appendix above mentioned the symmetry of the 32 classes is indicated by diagrams giving the general forms of etched figures. A brief and clear account of space-lattices is given in an appendix dealing with theories of crystal-structure.

The optical properties of crystals are treated in almost as much detail as the geometrical relations, and should be of value to the student. As remarked in the preface, however, the introduction of both Fresnel's ellipsoid and the indicatrix may be at first somewhat confusing. Of the remaining chapters in Part I, that dealing with the relations between the properties of minerals may be specially mentioned; the remarks on solid solutions, for example, are such as are to be found in no other general textbook of mineralogy.

In Part II, devoted to descriptive mineralogy, no attempt has been made to give a complete list of all the perfectly or imperfectly known mineral species. The author's aim has been rather to give a readable and detailed description of certain minerals selected as types, and to compare other less important species with these types. Rare minerals are sometimes mentioned with the object of elucidating the inter-relations of groups, but no doubtful minerals receive mention. At the head of the description of each type-species is printed in smaller type an enumeration of the principal characters of the species, an arrangement useful for purposes of reference. In place of the usual list of localities is given a description of the mode

of occurrence, associations, etc., of specimens from one or two typical localities. Much of the tabular matter, only necessary for purposes of reference, is collected together in appendices. The tables of minerals arranged according to their refractive index, optic axial angle, specific gravity, etc., will be of great use even to working mineralogists.

Finally, the printing and arrangement of the whole book leave nothing to be desired, while a very complete and systematic table of contents and an equally complete and well-arranged index add much to the value of the work. The only drawback to the book is its high price, which we are afraid will make a wide circulation impossible. If the costliness of the work is due to the inclusion of the coloured plates, we are of opinion that these had been better omitted, since they represent only one type of interference figure and form but an incomplete series.

III.—The Borneo Expedition.

Geological Explorations in Central Borneo, 1893–94. By Dr. G. A. F. Molengraaff. With 89 Illustrations in the text, 56 Plates, 3 Maps, and an Atlas (folio) of 22 Geological Maps. English Revised Edition, with an Appendix on Fossil Radiolaria of Central Borneo by Dr. G. J. Hinde. London: Kegan Paul & Co., Ltd., 1902. Quarto: pp. xx, 530; Appendix, pp. 56, pls. iv. Published by the Society for the Promotion of the Scientific Exploration of the Dutch Colonies. Leyden, E. J. Brill; Amsterdam, H. Gerlings. Issued February, 1903. Price £2 12*s.* 6*d.* net.

IT is with no common interest that we have studied the fine volume of text and illustrations, and the large folio atlas of maps which accompanies it, prepared by Dr. Molengraaff and printed in so admirable a manner by our Dutch neighbours (in both an English and a Dutch edition), an undertaking which, although warmly supported by the Dutch Colonial Government, really results from the enterprising spirit of "the Society for the Promotion of the Scientific Exploration of the Dutch Colonies," and sets before our own "Royal Colonial Institute" a splendid example which they would do well to follow.

A considerable delay has arisen in the production of this great work owing to the fact that, soon after Dr. Molengraaff's return to Europe from Borneo, in January, 1895, he was appointed State Geologist to the Transvaal; the preface to the first Dutch edition being dated from *Pretoria*, October 1st, 1899; that of the English edition from Hilversum, March 25th, 1902; but this edition, however, was not really issued until February, 1903.

A glance at the map of Borneo conveys to the mind the idea of vastness. It is one of the largest islands on the globe, being next after New Guinea in extent, and only outrivalled in area by two others, viz. Australia and Greenland, which usually rank as continents. It lies across the equator (7° N. and 4° S.), forming

one of the greatest of the East Indian Archipelago, and having an area of 280,000 square miles. Visited first by the Venetian traveller Ludovico Varthema, about 1505, it was next reached by Spain in 1521; the Portuguese followed and established a few ports in 1526, and carried on trade with the natives for over 150 years. The Dutch reached Borneo at the close of the sixteenth century, and remained there for 70 years. The English followed and settled at Bandjermassin in the south till the beginning of the eighteenth century, when they abandoned it owing to the hostility of the natives. The Dutch then returned, and have since 1733 slowly increased their territory, and now hold more than two-thirds of the whole island; but the district of Sarawak, on the west coast, under Raja H.H. Sir C. J. Brooke, the northern part called British North Borneo, controlled by a Chartered Company, and the native Sultanate of Brunei, all these three (covering an area of about 84,000 square miles) are under British protection.

Borneo is a country of high mountains, heavy rainfall, tropical forests, and big rivers everywhere; and, although known to Europeans for nearly 400 years, its interior is still a virgin field for the naturalist and the explorer.

Ethnologically it is a wonderful country, with a mixed population composed mostly of Dyaks, with a large number of Malays and Chinese. Here, on the coasts and in the estuaries and rivers, or on the land for that matter, we have the native race, the Dyaks, living in large communal pile-dwellings; in Brunei, for instance, a population of nearly 7,000 may be found to-day living in dwellings built *entirely on the water*, communication being only possible by boat. In South and East Dutch Borneo the chief town is Bandjermassin on the Riam-kina River; here, again, most of the inhabitants are found living either in *floating raft-houses* (rising and falling with the level of the water) or in pile-dwellings. Those on the land are also built on piles, and are often stockaded around after the manner of the neolithic palisaded and stockaded *terramare* discovered in the Po valley between Parma and Modena; while those on the water are likewise present-day survivals of the precisely similar Swiss and Italian pile-dwellings of prehistoric times. Thus the axiom still holds good, "that man under analogous circumstances acts in an analogous manner irrespective of time and space" (F. Troyon).

The region of Dr. Molengraaff's geological explorations is situated principally in the north-eastern portion of the political division of Dutch West Borneo, and forms part of Central Borneo. It is traversed from east to west by the great river Kapoewas, which takes its rise in the hilly districts of the extreme north-easterly margin of the division, and in its course to the sea receives the waters of numerous large and important tributaries, which flow to it from the mountainous regions bordering both the north and south sides of its basin. The total length of this river, from its source to the sea, is stated to be 1,143 kilometres (710 miles), about 24 kilometres longer than the Rhine. On the north side of the Kapoewas basin is the mountain range known as the Upper Kapoewas, which

separates it from Sarawak, and towards the south are the Muller mountains, the elevated Madi plateau, and the Schwaner range, which forms the division between it and South Borneo.

The river Kapoewas forms the main highway of communication, and from villages and stations on its banks the author obtained native boats and helpers, with which he made the ascent of the various tributaries as far as practicable, and when the streams no longer served, the land-route to the mountain ranges and peaks had to be resorted to. But in a country of tropical forest growth such as Borneo it is next to impossible to perform any long journeys on foot; the native Dyak footpaths through the forest—the only land communication—are merely narrow tracks, just wide enough for a single man; they follow a nearly straight course, breasting steep hills and scaling the sides of mountains without a zigzag; they are not diverted by morasses or streams, deep gorges are simply bridged over by trunks of trees, and the only obstacles they bend round are lofty forest trees. As a consequence, land travel is very fatiguing to Europeans. Nor is the journey by boat up the streams in Borneo without its dangers and difficulties, mainly caused by the frequent waterfalls and rapids, where ledges of hard rock cross the river bed and necessitate unloading and a portage; the streams, moreover, are liable to sudden and dangerous spates.

Dr. Molengraaff found that the lines of dislocation of the rocks in the Upper Kapoewas territory followed a generally east and west trend, and this led him to infer that by taking a route from north to south a continuous geological section from the boundary of Sarawak on the north, right across Dutch Borneo to the Java Sea, might be observed. This course was adopted on his return journey, and, starting from Boenoet on the Kapoewas, he travelled southward, crossed the Madi plateau, and, reaching the Schwaner range, made the ascent of Mount Raja, one of the highest peaks (2,278 metres). At Mount Boenjau the water-parting between West and South Borneo was crossed, and descending the Menjoekoei river to its junction with the Samba river, and thence by the great river Katingan, he reached Pegattan, close to the coast, on the 28th October, 1894, and four days afterwards arrived at Bandjermassin by sea. The journey down-stream of 300 miles (not counting river curves) was accomplished in a fortnight. The territory traversed by this southern route was absolutely unexplored scientifically, and the greater part of it had not previously been reached by any European, so that the physical and geological descriptions of it given by Dr. Molengraaff in chapters x, and xi, are of the greatest interest.

The principal end of the expedition, to ascertain the nature and the relative succession of the rocks of Central Borneo, which may be said to be the core of the island, has been successfully carried out by the author, and from his observations we obtain for the first time a satisfactory outline sketch of its geological features. The oldest rocks recognized are strongly folded, amphibolite and chlorite schists and quartzitic slates occurring in the hilly country near

Sĕmitau and other localities. Petrographically they are similar to crystalline schists of Archæan age, but it is possible that they are only sediments altered by granite intrusions.

Next, above the doubtful schists, there is a great thickness of phyllitic clay-slate with a silky lustre, alternating with beds of sandstone, greywacke, and quartzite. The strata are nearly vertical. No fossils have been found, and its age is therefore unknown, though very possibly it is Palæozoic. It has been named the "Old Slate Formation." The Upper Kapoewas range, a typical mountain chain much worn down by erosion, which runs nearly east and west and forms the boundary between West Borneo and Sarawak, and between West and East Borneo for a distance of 225 kilometres, is mainly built up of these slaty strata. On the south side of the range the beds are abruptly cut off by a great fault.

The next younger formation, known as the "Danau Formation," is composed of highly tilted and contorted beds of chert, jasper, and hornstone, quartzite, clay-slate, sandstone, diabase, diabase-tuff, and porphyrite, which have been brought down to the level of the "Old Slate Formation" by a fault. The beds have an east and west strike, and they have been traced from the Lake district for a distance of 280 kilometres, quite into East Borneo. The chert, jasper, and hornstone beds are of organic origin, and are mainly composed of Radiolaria. In the Upper Kapoewas region their thickness is estimated at 100 metres, and they are regarded by the author as deep-sea deposits. The beds of diabase and diabase-tuff, which alternate with the chert and hornstone, are attributed to submarine and volcanic eruptions. Some of the tuff beds likewise contain Radiolaria. This formation is of pre-Cretaceous age, and the Radiolarian beds are probably Jurassic.

A system of moderately tilted and folded beds of marly and sandy deposits succeeds the Danau formation. Along the river Seberoewang the marls contain *Orbitolina concava*, which indicates that they are of Cenomanian (Upper Greensand) age. The deposits were probably laid down near a coast, and a portion of Central Borneo must then have been dry land. The rocks occur in various localities, and extend to the south of the Madi plateau.

The oldest Tertiary deposits in Central Borneo have not been met with *in situ*; they are only known from boulders of grit, containing *Nummulites* and *Orbitoides*, which occur in the valleys of the rivers Embaloeh and Tekelan; they may be regarded as of Oligocene age.

An enormous area is covered by a formation named the Old Tertiary or Mĕlawi Group, which consists of horizontal beds of sandstone, quartzitic sandstone, and claystone, with intercalated seams of coal. Molluscan shells occur in these beds in places; according to Krause and Martin they are brackish-water forms, which probably lived in estuaries. At the time of their deposition the whole of Central Borneo, with the exception of the Upper Kapoewas range, was submerged beneath the sea. The greater part of the Madi plateau and the Schwaner range, which separates West from South Borneo, are formed of these rocks.

The coal-seams in these Tertiary beds appear to be formed of plant débris and trees brought down by the river floods, and not of slowly formed vegetable growths *in situ*, as is the case with most Palæozoic coal-seams. As a rule, the Borneo coal is too much mixed up with sand and clay to be of economic value, but the author records several localities where the beds are of sufficient purity and thickness to be worth prospecting for mining purposes. They are shown on the north shore of the Kenepai river (p. 38); on the Mondai river (p. 60; also Atlas, Map 6, sect. F & H); below Karangan Pandjang (p. 273); on the Sĕkilit, a tributary of the Tĕbaoeng, several layers of fairly good but somewhat fissile coal were exposed (profile B, Map ix*a*, pp. 288 and 293); and again on the Pinoh river, where a bed of coal of inferior quality rests on claystone beds with concretions and numerous shells (see section p. 142, fig. 35).

Succeeding the Old Tertiary Sandstone formation, there are extensive deposits of fluviatile and lacustrine origin, consisting of beds of fine sand and mud mingled with vegetable débris, which are regarded as probably of Quaternary age; but in Borneo there is such a close resemblance in the sandstones and clays of different ages that in the absence of fossils it is almost impossible to determine between those of Tertiary, Quaternary, and recent dates.

Owing to the heavy tropical rainfall, the denudation of the higher land-areas in Borneo is on an enormous scale, and the gravels, sands, and finer materials brought down by the rivers are spread over extensive areas. Thus in West Borneo, which has a total area of 145,000 square kilometres, it is estimated that 30,000, or nearly one-fifth, are covered deeply with alluvial deposits.

Between the hills and the flat alluvial grounds of most of the large rivers, there are older fluviatile deposits of a gravelly character, which generally contain gold. The gold is obtained by Chinese, who work the beds in a very primitive manner. They are very reticent respecting the results of their operations, which are probably not over remunerative, but if hydraulic machinery were employed the chances of success would be greater.

All the later changes in Borneo appear to be due to atmospheric influences, which have greatly diminished the height of the island, and at the same time enlarged its circumference by the rapid deposition of the alluvial material brought down by the rivers. The finer materials are carried far out to sea, and, from the discoloration of the water round the coasts, Borneo has received its name of "Mudland."

Intrusive and eruptive rocks are largely developed in Central and South Borneo. Granite areas occur in the Schwaner mountains, the base of which principally consists of this rock, and in the bordering hilly districts of South Borneo; also in the Sĕmitau Hills, the Boengan Hills, and the lake district. It is mainly an amphibole-biotite-granite with plagioclase, which frequently passes into tonalite. Its intrusive character is proved by the intense alteration of the surrounding rocks near the zone of contact.

Diorite, gabbro, norite, peridotite, serpentine, and diabase have been met with in different districts.

There are three principal volcanic areas in Central Borneo, the Muller mountains, the northern slope of the Schwaner mountains, and on the Samba river. The most important is the Muller range, forming the south boundary of the Upper Kapoewas plain; its known extent in an east and west direction is 280 kilometres, and its average breadth about 45 kilometres. The whole of the range consists of volcanic rocks; those of the western portion are of a decidedly andesitic character, and those of the eastern of rhyolitic and dacite types. Thick beds of tuff are also present in which there are large quantities of silicified wood, partly stems of trees still in an upright position. The average height of the mountain peaks, which are mere fragments of a former unbroken tuff-plateau, is about 1,100 metres. The volcanic action which produced these mountains is believed to have commenced during or shortly after the Cretaceous age, and, after continuing through the Tertiary, terminated probably about the commencement of the Quaternary period.

In an appendix, Dr. G. J. Hinde gives a description of the Radiolaria which form a large part of the chert, hornstone, and jasper series of rocks, and are present also in the alternating beds of diabase-tuffs, marls, etc., belonging to the Danau formation, mentioned above. The unexpected discovery of these siliceous organic rocks in Central Borneo by Dr. Molengraaff is of considerable interest in view of the fact that within the last few years rocks of a similar character have been found in other parts of the East Indian Archipelago, at Celebes and Billiton, and also in various parts of Europe, in California, Australia, and Japan.

About one hundred different forms of Radiolaria were recognized and described in thin sections of these Central Borneo rocks, and figures of them, carefully drawn by Mr. A. T. Hollick, are given on the accompanying Plates. Of these forms, seventeen occur in the rocks of other countries, and eighty-three are at present only known to Borneo. They show many points of resemblance to the Radiolaria present in rocks of Jurassic age in Switzerland and Italy, and to those of approximately the same age in the coast ranges of California, and it is highly probable that the deposits in Central Borneo in which they occur are likewise of Jurassic age.

In concluding our notice of this most interesting and valuable work, we wish particularly to call attention to the series of maps, charts, and sections in the atlas, and to the striking photographs, illustrating the natural scenery and geological structure of the country, and giving lively reproductions of the people, their homes, both for the living and the dead, and the strangely carved figures and memorial poles which surround their settlements. In the charts of the rivers the salient geographical and geological features of every portion of their course are carefully noted, and the geologically coloured maps and sections enable the reader readily to follow the observations recorded in the text.

The author acknowledges his obligations to Messrs. Schlumberger and R. Bullen Newton for determining the Nummulites; to Dr. Krause

and Professor Martin for examining the shells; and to Dr. Schroeder van der Kolk for assisting in the microscopic study of the rocks.

In the preface to the English edition Dr. Molengraaff specially thanks Dr. G. J. Hinde for reading the proofs and revises, and to this supervision may perhaps be attributed the general absence of errors in the text, which are usually too prominent in translations printed abroad. A separate vocabulary of Dyak names of places and things (most of which are given in notes or in the text and index, but *not collectively*) would have proved of service to English readers.

We commend the work to all who are interested in the geology of the East Indies, and hope it will find a place in all the public reference libraries in Britain and America and the Colonies.

IV.—A New Rock-Classification.

Quantitative Classification of Igneous Rocks, based on Chemical and Mineralogical Characters, with a Systematic Nomenclature. By Whitman Cross, Joseph P. Iddings, Louis V. Pirsson, Henry S. Washington. 8vo; pp. 286. (Chicago, 1903.)

THE classification of the igneous rocks is a question which has engaged the attention of many petrologists; and, as a wide divergence of opinion sufficiently attests, it involves problems of much difficulty. The memoir before us is the joint production of four well-known American authorities, and represents, we are told, an exhaustive discussion of the subject extending over many years. Moreover, it is not merely a contribution to a vexed question, but aims at affecting a final settlement of it. For these reasons the scheme put forward, and the arguments upon which it is based, demand a frank and careful consideration.

Our authors start from the proposition, which will scarcely be disputed, that existing methods of classification are illogical and in many respects unsatisfactory. But we are by no means convinced that they have correctly diagnosed the imperfections of the schemes in present use; and on such diagnosis the success of any proposed remedy must necessarily depend. The confusion which prevails in the classification of igneous rocks is in some measure due to causes inherent in the nature of the subject-matter, and especially to the absence of any well-defined 'species,' such as constitute the units of classification in the sister sciences. But the present difficulty is, as it appears to us, attributable in a much greater degree to the rapid and unequal growth of the science of petrology. Fifty years ago the classification of igneous rocks was of the crudest kind, but it seems to have been quite adequate to the state of knowledge at that time. The great revival of petrographical research which followed the introduction of microscopical methods has instigated a large body of workers, and the annual output, especially from the German laboratories, has attained a very considerable volume. The great bulk of this work is of a purely descriptive kind—petrography in

the strict sense. Much of it is doubtless of great value; but its value can be only very partially realised, for the reason that this accumulation of material has far outstripped the other side of the science, the business of which is to co-ordinate the scattered observations and bring to light the principles which underlie them. The pearls are there, but there is no thread on which we can string them. During recent years, however, we have witnessed many indications of a reaction from this state of things. From various quarters memoirs have been put forth in which very broad views are taken of the groups of rocks dealt with, the question of their mode of origin being kept constantly in sight. We may remark in passing that American petrologists, including some whose names appear at the head of this article, have taken their part in the advance on these lines. Much stress is now made on the essential mutual relationships of associated rock-types, and Brögger has gone so far as to give a provisional genealogical tree for those of the area which he has made his own. Such essays in the direction of a comprehensive genetic treatment are necessarily tentative, but we have no sympathy with those who would dismiss them as mere speculation. Their influence is already very apparent. Petrologists feel that they have almost within grasp a fundamental principle analogous to that of descent, which lies at the root of classification in the organic world; and this warrants a confident hope that there may emerge in due time a truly natural classification of igneous rocks. If the expectant attitude of mind here suggested is, as we think, very general, the appearance of an elaborate artificial scheme at the present juncture will seem to many a step in the wrong direction.

The standpoint of the authors is clearly defined in one of their prefatory remarks: "The present systems are to a certain extent founded on theory or hypothesis, while classification in order to be stable must eschew all such bases, and be founded only on ascertained facts."

As interpreted by what follows, the stability here made a desideratum must be understood as rigidity; for the argument leads to the setting up of an unyielding framework, in which, between the arbitrary partitions, each rock, whether discovered or undiscovered, may find its appropriate pigeonhole. Although we are under the disadvantage of having no alternative scheme to offer, we venture to submit that an elastic classification, embodying what is known and capable of being adapted to the requirements of increased knowledge, might with equal propriety be described as founded on ascertained facts. At least, it may be pleaded with some reason that existing systems fail, not because they involve a certain element of hypothesis, but in some measure because their implied hypotheses are fallacious.

Some criticism on general grounds we have thought admissible; but the scheme before us is professedly empirical, and we cannot do justice to it without adopting for the purpose the same point of view. The first impression of complexity, due partly to the strange

terminology introduced, is not a just one. The principles upon which the whole assemblage of igneous rocks is divided and subdivided are, at least on the face of things, perfectly simple, and they are carried out logically and consistently throughout. The criteria appealed to are, moreover, of a strictly quantitative kind, so that all ambiguity and compromise are excluded, manifestly an advantage if our object is to provide each rock with a precise systematic position and name. It follows, of course, since the hard dividing lines have no counterpart in nature, that rocks having the closest affinities must sometimes be divorced; but this is a drawback incident to any arbitrary scheme.

The basis of classification is mineralogical composition, though this rough statement needs, as we shall see, important qualification. The mineralogical criteria selected are such as correspond with more or less important differences among the rocks themselves, and those which are deemed of most importance are used in making the major divisions of the scheme, the principle being carried out, as it seems to us, with skill and judgment. Thus the rock-forming minerals are first grouped under two heads, the siliceous and aluminous on the one hand and the ferro-magnesian on the other, or, as we may conveniently say, the light and the dark. The whole of the igneous rocks are then divided into five great classes, according to the ratio which the total light minerals bear to the total dark:—

(i) Light minerals extremely abundant; ratio greater than 7 : 1.
(ii) Light minerals dominant; ratio between 7 : 1 and 5 : 3.
(iii) Light and dark minerals nearly equal; ratio between 5 : 3 and 3 : 5.
(iv) Dark minerals dominant; ratio between 3 : 5 and 1 : 7.
(v) Dark minerals extremely abundant; ratio less than 1 : 7.

This we may regard as in some sense an extension of Brögger's leucocratic and melanocratic groups. In the first three classes subdivisions are made with reference to the nature of the white minerals, five subclasses being defined in each class according to the ratio of quartz, felspars, and felspathoids on the one hand to corundum and zircon on the other. In the last two classes, where dark minerals preponderate, these are made the basis of a like subdivision, the critical ratio adopted being that of pyroxenes, olivine, and magnetite to apatite, etc. This produces an ill-balanced arrangement, for it is evident that in every class the first subclass must greatly outweigh all the others. It is, however, easier to criticise the scheme in these particulars than to improve it. It is not possible here to follow out all the details of this ingenious arrangement, and we will only note how the subclasses are divided into orders. In the first three classes this is effected with reference to the preponderance of quartz, felspars, or felspathoids among the white minerals. Since quartz and the felspathoids are 'antithetical,' not being found in company in igneous rocks, it is possible here to use at once the ratios of quartz to felspars and felspars to felspathoids; which leads to nine orders in each subclass, the dividing ratios being

the same as before. In classes iv and v each subclass is divided into five orders, according to the ratio of pyroxenes and olivine to iron-ores. By further particularisation of the constituent minerals the authors establish successively suborders, rangs, subrangs, grads, and subgrads. The reason given for the spellings 'rang' and 'grad' is that 'rank' and 'grade' are so frequently employed in a general sense, but this consideration will not console French and German readers. For our part, we are loth to see the words 'class' and 'order' tied up to special meanings, and should have preferred to borrow such terms as 'domain' and 'nome' from the vocabulary of the older systematists.

This leads us to notice that the new classification is expressed throughout in terms of a new nomenclature. Given the one, we must indeed grant the necessity for the other. As the authors justly remark, petrology has suffered sufficiently from the redefining of terms, a license which would not be patiently conceded in any other branch of science. It is, moreover, a part of their design that each term shall carry its own precise meaning on its face. To this end they have boldly thrown aside the Greek lexicon, and constructed new words, each of which is a frank barbarism, but conveys an explicit meaning on a certain mnemonical plan. Thus the two groups of minerals, which we have distinguished above as the light and the dark, are designated by what the late Lewis Carroll called 'portmanteau-words'; *salic*, recalling *s*-ilica and *al*-umina, and *femic*, suggesting ferro-magnesian. The five classes of rocks are named persalic, dosalic, salfemic, dofemic, and perfemic. A like method is pursued through all the minor divisions. In spite of its obvious utility, it has at first a decidedly irritating effect, and will not improbably prejudice the reception of the scheme. These uncouth classificatory terms, however, need not be often used in speaking of the rocks themselves, for each subdivision inferior to subclass is provided with a proper name derived from some country or locality where the rocks are typically exhibited. We have thus, for a granodiorite from the Yosemite, the order Britannare, rang Toscanase, subrang Toscanose. Different terminations are used to mark divisions of different magnitude or status, a feature which, we think, must be commended. The termination *-ite* is at present greatly overworked, and a novice might plausibly suppose lherzolite to be something of equal importance with granite.

The only serious criticism that we have to make upon the new classification, regarded as a purely empirical scheme, remains to be noticed. The percentage mineralogical composition which is the basis of classification is an *ideal* one, which may or may not agree with the actual composition, and in some cases departs widely from it. Thus the leucitite of Capo di Bove is assumed, for the purpose of fixing its systematic position, to contain about 11 per cent. of anorthite and 9 per cent. each of olivine and akermanite, although none of these minerals is actually present in the rock. Some of the actual constituents, melilite and biotite, are discarded, because their complex formulæ make them unsuitable to be included in the list of

'standard' minerals recognized in the scheme. The authors would justify this treatment, "not only by the fact of the variable possibilities of crystallization in one magma, but because of the difficulty of determining the quantity and chemical character of the minerals actually present in many rocks. It is further warranted because of the impossibility of determining the minerals in a great number of rocks in which they are too small, and because of the incomplete crystallization of all more or less glassy rocks."

It seems to us that artificiality is here pushed to the extreme limit, and an element of complexity, very burdensome in practice, is dragged in. Rules of an elaborate kind, though presumably sufficiently definite, are given for calculating the ideal mineral composition or 'norm' from the chemical analysis of the rock. Further, we are told that a knowledge of the actual mineral constituents and their true percentages, even when they are all 'standard' minerals, is not sufficient; we must calculate from this to the chemical composition, and thence back to the norm. The norm is thus merely a circuitous device for presenting the chemical composition, and we are tempted to ask why the latter was not taken directly as the basis of classification. A scheme beginning with five classes defined by silica-percentage, and proceeding to minor divisions with respect to the other chemical constituents, would seem to offer the advantages without the drawbacks of the scheme before us. It must at least be recognized that the quantitative precision which is the characteristic of this system recoils upon its inventors, since a like minute accuracy is requisite in the diagnosis of every rock-specimen. We question whether a given rock could ever be referred with complete confidence to its place in this scheme in the absence of a trustworthy bulk-analysis, and even this might fail unless a perfectly fresh specimen were forthcoming.

It is impossible in the space at our disposal to present a complete account of the scheme with all its ingeniously contrived details. If we have in any respect misapprehended its scope, we must plead the complete novelty of the system and its elaborate aspect upon a first view. Assuredly we have not approached it in any unfriendly spirit, saving only the predilection we have avowed for a more natural treatment, or, in other words, our desire to see the Gordian knot untied and not cut. There remains the consideration that the success of what purports to be a practical scheme depends ultimately upon its innate power of commending itself to practical workers. We learn that the new classification has already gained adherents in America, but we doubt whether it will find favour, e.g., in the German Universities, from which so large a proportion of our petrographical work emanates. It suggests, partly perhaps by its quaint nomenclature, a comparison with Volapük and Esperanto. Now there is something in human nature which ordains that languages shall grow, and not be produced ready-made; and, whether we call this stubborn conservatism or an instinctive grasp of the evolution philosophy, it insinuates a foreboding for the scheme before us, no less than for its terminology.

Our criticism, so far of a merely destructive kind, will be made more intelligible if we may be allowed to indicate roughly the lines on which, as we think, a real advance may be looked for. Instead of beginning at the top and dividing down, we would begin at the bottom and build up. The unit of classification would be the sufficiently definite entity usually spoken of as a rock-type. The necessity for a given type being once established, and the characters of the type clearly defined, it should receive a name, preferably derived, as is customary, from the type-locality; and thereafter any attempt to alter the definition, or to extend the name beyond it, should be firmly resisted. If this proviso could be secured, the often-heard objection to the multiplication of names would become merely an objection to the increase of knowledge. Concurrently with the settlement of known types and the investigation of new ones, we should expect to gain a clearer insight into their mutual relations from the genetic point of view, and the information thus acquired, in the field as well as in the laboratory, would enable us in due time to group the types into a natural system expressing our knowledge of their chemical, geological, and geographical relationships. In such a system there would be no finality; indeed, its changes would be in some degree a measure of the progress of petrological science. The conception is one far removed from that embodied in the scheme now before us. It is true that a natural and an artificial system might conceivably exist side by side, each being employed for its appropriate purposes. Such a dual classification is evidently contemplated by the authors, when, for instance, they expressly leave the terms 'family' and 'series' free for use in a petrogenetic connection. It is easy to see, however, that the case of petrology differs in fundamental respects from that of botany, and we cannot doubt that the general adoption of a fixed empirical scheme would greatly hinder the development of a natural classification at some future time. Whether the present bold proposal meets in a convenient manner the immediate requirements of petrography is a different question, and one which will find its true answer in the reception accorded to the scheme by the general body of workers.

In conclusion, we may state that the exposition of the system by its inventors leaves nothing to be desired in respect of lucidity and precision. It is reprinted, together with an admirable historical survey of rock-classification by Dr. Whitman Cross, from the Journal of Geology. The volume contains certain additions, including a useful glossary, which inspires the reflection that compositors and proof-readers will not be among those who welcome the new terminology. The book seems, however, to be carefully corrected, and is brought out in a form which fully maintains the reputation of the University of Chicago Press.

A. H.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—February 20th, 1903.—Professor Charles Lapworth, LL.D., F.R.S., President, in the Chair.

Annual General Meeting.

The reports of the Council and of the Library and Museum Committee for the year 1902, proofs of which had been previously distributed to the Fellows, were read. After premising that the Society continues to be generally in a flourishing condition, the Council stated that the number of Fellows had undergone but little change in 1902. The number elected was 48 (4 less than in 1901), of whom 30 qualified before the end of the year, making, with 18 previously elected Fellows, a total accession of 48 in the course of the twelve months under review. During the same period, the losses by death, resignation, and removal amounted to 41, the actual increase in the number of Fellows being therefore 7 (as compared with a decrease of 4 in 1901). The total number of Fellows on December 31st, 1902, was 1,258.

The balance-sheet for that year showed receipts to the amount of £3,439 16*s.* 3*d.* (including a balance of £403 12*s.* 3*d.* brought forward from the previous year), and an expenditure of £3,128 8*s.* 7*d.* (exclusive of the sum of £250 invested in Natal Government 3 per cent. stock).

The issue of the Catalogue of Type and other important Specimens in the Society's Museum, based on Mr. Sherborn's manuscript catalogue, edited and prepared for publication by the Rev. J. F. Blake (to whom the Society are greatly indebted), was also announced.

The reports having been received, the President handed the Wollaston Medal, awarded to Professor Heinrich Rosenbusch, For. Memb. G.S., of Heidelberg, to Professor W. J. Sollas, M.A., D.Sc., F.R.S., for transmission to the recipient, addressing him as follows :—Professor Sollas,—

No man has exercised a greater influence on the progress of petrological science than Professor Rosenbusch. Though a master of detail, he has always insisted on the important bearing of microscopical studies on many of the great theoretical problems of modern geology.

In his celebrated researches on the Steigen Schiefer he combined stratigraphical, mineralogical, and chemical data in such a manner that his memoir must for all time remain a classic in geological literature. His subsequent work is all of the same philosophical character, and every question that he has handled has been fundamentally modified and notably advanced as the result of his investigations. The fertility which he has shown, in the production of new and often profound theories, has only been equalled by the courage with which he has discarded the old so soon as they have proved unsatisfactory or incomplete.

The successive editions of his great work on the microscopic characters of minerals and rocks have been landmarks in the progress of the science. The range of his knowledge therein revealed is enormous, yet we never feel that his writings are overburdened with detail, because of the power of philosophical generalization with which he marshals his facts, and reduces the whole to a consistent and well co-ordinated unity.

As a teacher Professor Rosenbusch has especially excelled, and the devotion and enthusiasm both of himself and his pupils have greatly helped to awaken the interest of geologists in petrological investigations, and to give to these investigations the prominent position that they now occupy.

The Council of the Geological Society make the award of their Wollaston Medal to Professor Rosenbusch in grateful appreciation of these pre-eminent services to geological science.

Professor Sollas, in reply, read the following letter which had been forwarded by the recipient:—Mr. President,—

"Although the Geological Society, for many years past, has accustomed me to a most benevolent judgment of my scientific work, I feel greatly surprised by the award of the Wollaston Medal, the highest honour which the Council of this illustrious Society can bestow. I beg to offer my cordial thanks for this distinction, which I thought far beyond the limits of my aspirations.

"I may proudly confess to have passed a life of earnest and unceasing endeavour in the attempt to understand and to decipher those grand and mysterious documents, wherein the geological history of our mother Earth has been written down by Nature itself; but I am fully aware of the insignificance of the results obtained. Every word which it is our good fortune to decipher involves a new riddle, and so I daily repeat the first scientific experience of my infancy—that the art of spelling is a most difficult one.

"There are many members in this illustrious corporation to whom I owe a vast debt of scientific information and of personal encouragement. The high honour received at their hands on this day will be a stimulus to me for ever-renewed attempts to proceed on my onward way, γηράσκω δ'αἰεὶ πολλὰ διδασκόμενος. It will be, indeed, a great satisfaction to me, if the rest of my life's work prove not unworthy of the approbation of this ancient and renowned Society."

The President then presented the Murchison Medal to Dr. Charles Callaway, M.A., addressing him in the following words:—Dr. Callaway,—

Your work among the ancient rocks of Shropshire—Murchison's classical county—commenced as early as 1874, when you brought before this Society evidences of the occurrence of Tremadoc fossils in the so-called 'Bala' rocks of that area; but your conclusions were then in advance of the times. In your second paper, published in 1878, on a "New Area of Cambrian Rocks in Shropshire," however, you not only demonstrated by means of the abundance of fossils the accuracy of those conclusions, but you made that paper the starting-point of what, as afterwards carried out by yourself and others, has effected almost a revolution in our previous knowledge of much of the older half of Shropshire geology.

You first suggested in that paper the Archæan age of the Wrekin volcanic series, and in several subsequent papers you not only showed the extension of these volcanic and Cambrian rocks into the Caradoc area and elsewhere, but introduced into the geological literature of our older rock-groups the names Uriconian, Longmyndian, and Malvernian.

Your researches also in the Malvern Hills, in Anglesey, and in the complicated Assynt and other regions of the North-Western Highlands were all of them most fruitful in discovery, and stimulated the work of others in no ordinary degree. And of your later researches into the obscure phenomena of the crystalline and metamorphic rocks, much the same may be said. As one of those who have followed your track to their great comfort and benefit, and as one who has for more than thirty years been honoured by your friendship, it is a great pleasure to me to be permitted to hand you this Medal on behalf of the Council of the Geological Society.

Dr. Callaway replied as follows:—Mr. President,—

I am deeply sensible of the honour conferred upon me by the award of this Medal. It is to me a special gratification that it bears the name of Murchison, for the greater part of my work has been on ground rendered classic by his genius. We honour him as one of the chief of those who laid the foundations of our knowledge of the oldest rocks, and I am proud to have been able to add a few stones to the superstructure. That I receive this distinction at your hands is a peculiar pleasure. You also have

laboured long in the field of Archæan and Proterozoic geology. Your kind and generous appreciation has, therefore, a personal as well as an official value.

In presenting the Lyell Medal to Mr. Frederick William Rudler, late Curator of the Museum of Practical Geology, Jermyn Street, the President addressed him as follows:—Mr. Rudler,—

Our science demands for its progress not only men who discover new facts, but also men who will explain and illustrate its facts and theories to those who are anxious to understand and to make use of them. There are few among those who have been both learners and workers in the science during the last thirty years who do not retain grateful memories of the instruction and assistance which at one time or another you have personally afforded them.

Further, our science needs for its appreciation by the economic world and the public those who, being familiar with the facts already gathered together, will present them in a clear and convincing form, and expound their practical applications. In this respect also you have done our science lasting service. Indeed, your long official career at the Museum of Practical Geology has been a record of unselfish devotion to the advancement of the practical and educational sides of geology.

In countless ways—in reviews, in the later editions of Ure's famous "Dictionary of Arts, Manufactures, and Mines"; in your masterly essays on "Experimental Geology," and on "Fifty Years' Progress in British Geology," delivered as Presidential Addresses before the Geologists' Association—not to mention anthropological and other addresses,—you have given evidence of your wide knowledge of the literature and substance of geology and the allied sciences, of your sound judgment, and of your exceptional capacity for transmitting to others the accurate knowledge which you possess.

It affords, therefore, to the Council of the Geological Society the greatest satisfaction to award to you the Lyell Medal, which, according to the words of its founder, is to be given to one who "has deserved well of the science."

Mr. Rudler replied in the following words:—Mr. President,—

To have the privilege of standing here as the recipient of a Medal is a far higher honour than I had ever dared to expect. While acknowledging most gratefully, though I feel most inadequately, the generous action of the Council in making this award, I am also anxious to express my deep sense of indebtedness to you, Sir, for the very indulgent words with which you have been so good as to enrich this presentation. If anything like personal detachment from such an award were permissible, I should like to be allowed to regard this as a token of sympathy between this Society and the institution with which I was so long connected, and where the ruling desire of every officer is—if I may use the words of the illustrious founder of this bequest, which you have just quoted—to deserve well of geological science. It is, Sir, a matter of extreme gratification to me that I should find myself unexpectedly honoured by the possession of a Medal founded by our great master, whom it was my privilege to know personally, and whose memory I so profoundly revere.

The President then presented the Bigsby Medal to Dr. Henry M. Ami, M.A., of the Canadian Geological Survey, addressing him as follows:—Dr. Ami,—

The members of the Geological Society who interest themselves in the Palæozoic formations of Britain and America, are well aware of the extent and importance of your work among the Palæozoic rocks and fossils of Canada. As Assistant-Palæontologist to the Canadian Survey, you have not only been for many years responsible for much of the classification and tabulation of the Lower Palæozoic fossils in the Museum of that Survey, but you have visited the places where they were collected in the field, and identified on the spot their local horizons. This two-sided knowledge has enabled you in several of your papers, such as those bearing on the "Geology of Quebec and its Neighbourhood," the "Utica Terrane," and the "Organic Remains and Geological Formations of the Eastern Townships," to throw much light on disputed questions of succession and stratigraphy.

Nor has your work been restricted to the older Palæozoic rocks. Your papers on the "Knoydart Formation of Nova Scotia," the "Carboniferous Formations of

Canada," etc., have done much to clear up the difficulties of the correlation of these formations with those of other countries. Neither must we forget the many papers in which you, with fulness of knowledge and great depth of sympathy, have laid before geologists and the public the lives and labours of those great pioneers who have accumulated the vast store of knowledge which we now possess of the rocks and fossils of the Dominion.

As an old friend and correspondent of yours, I am very pleased that it has fallen to my lot to hand you this Medal; and I can assure you, on behalf of the Council of the Geological Society of London, that it is a special gratification to them to award it to one whose work has been done in the country of the founder of the Medal himself, and among the rocks and fossils studied by him.

Dr. Ami replied in the following words:—Mr. President,—

I am deeply sensible of the great honour which the Council of this Society has conferred upon me. Especially am I gratified in receiving this award at the hands of one who has been so generous a counsellor and critic in matters geological for the past eighteen years. Words fail me to express in adequate terms the gratitude which fills me at present. Suffice it to say that, through the liberality of the Canadian Government and courtesy of the Hon. the Minister of the Interior (Mr. Clifford Sifton), Head of the Geological Survey Department at Ottawa, I have acceded to his wishes, and come over in person to receive at your hands the award so generously made.

It is always a source of inspiration to come to London, the centre of thought, the fountain-head of research, and radiator of power; and, believe me, that, combined with the pleasure and privilege of attending one of the anniversary meetings of this Society, of which I have been a humble Fellow for some eighteen years, there lurked in my mind the thought of gain in valuable information during my stay, which I know will enable me all the better and more intelligently to carry out the special work on the Silurian faunas and succession of Eastern Canada which has been entrusted to me.

That my name should become associated with that of the late Dr. Bigsby, founder of the Medal, is a matter of which I have great reason to be proud. Bigsby was a pioneer in British North American geology. It has been my lot and good fortune recently to collect all the data relating to the geological history of the Grand Manitoulin and adjacent islands of Palæozoic age in the Lake Huron district of Canada, and it may not be uninteresting to state here that, when the unexpected news of this award reached me in Ottawa, I had then completed, and on my desk, a synopsis of Dr. Bigsby's geological explorations in that region during the early years of the last century.

In conclusion, permit me to add that I am deeply moved at this moment by the thought of what the acceptance of the Bigsby Medal on my part involves. There is undoubtedly associated with it a solemn pledge and obligation to prosecute geological research-work still farther. If I am spared, Sir, it will be my highest endeavour as well as pleasure and privilege to follow in the footsteps of those eminent geologists in the distinguished list of recipients of the Medal founded through the generosity of the late Dr. Bigsby, and prove not unworthy of the marked distinction that the Council have conferred upon me this day.

The President, in handing the Prestwich Medal, awarded to John, Baron Avebury, P.C., F.R.S., to Professor T. G. Bonney, D.Sc., F.R.S., for transmission to the recipient, addressed him in the following words:—Professor Bonney,—

Sir John Lubbock, now the Right Hon. Lord Avebury, P.C., became a Fellow of this Society in 1855. He was one of those who took a warm interest in the question of the antiquity of man, in those early days when it was so much in dispute. He did much to support the new views, not only by a paper in the Natural History Review, but also by his work on "Prehistoric Times," in which that paper was subsequently incorporated. In those days he was closely associated with Sir Joseph Prestwich (who at that time had not yet been called to the professorial chair at Oxford), and, along with Sir John Evans, frequently accompanied him and other Fellows of the Society on geological excursions in France and elsewhere, investigating not only the evidences of the antiquity of man, but other problems of special interest in geology.

Since then, notwithstanding his numerous public avocations, his important business occupations, and his researches in natural history, both entomological and botanical, he has always retained a lasting attachment to geology. He has evinced this, not only in keeping abreast with its progress and accompanying its workers in the field, but also in the publication of works on geology, marked by his own literary charm. His recent works on the scenery of Switzerland and of England have done much to create a deep appreciation and sympathy for the science among the thinking and educated public.

Whether, therefore, from old associations, or from the special nature of his geological researches, or from the fascination of his geological works, the Council of the Geological Society feel that he is a most fitting recipient of the first gold medal struck in accordance with the testamentary dispositions of our venerable Fellow, Sir Joseph Prestwich.

Professor Bonney, in reply, read the following letter which had been forwarded to him by the recipient:—Mr. President,—

"I should have felt it a great compliment in any case that the Geological Society should have bestowed upon me one of their medals, but I am specially gratified to have received the first of the Medals instituted in honour of my old friend Sir Joseph Prestwich. It is now more than forty years since I first visited the valley of the Somme under his guidance and that of M. Boucher de Perthes. Since then I have had the advantage of making many most instructive excursions with him. On those occasions we were out early and late. Meals constantly gave way to gravel-pits. On one occasion I spent a week with him in Paris—at least, if we can be said to have been in Paris, when I think that we were never there between 7 o'clock in the morning and 8 in the evening; and I look back on those expeditions with the greatest interest. I shall value the Medal extremely, both as a mark of the approval of the Council, and also in memory of one whom I esteemed so highly, and to whom I owed so much. It is a matter of great regret to me that absence from England has precluded me from attending to receive it personally."

The President then presented the Balance of the Proceeds of the Wollaston Donation Fund to Mr. L. L. Belinfante, M.Sc., Assistant Secretary of the Geological Society, addressing him as follows:—Mr. Belinfante,—

At a meeting of Fellows of the Geological Society it is quite unnecessary for me to say anything as to your merits. You stand here among friends and well-wishers, to all of whom you are well known as the capable Assistant Secretary of the Society. But perhaps it is to the Council alone, and more particularly to those who have served as officers, that the full extent of the indebtedness of the Society to you is known. You combine the offices of Assistant Secretary, Clerk, Librarian, Editor of the Journal, and Curator of the Museum, and each of these offices, whether the duties are performed by you personally or under your general supervision, are filled to the great advantage of the Society. Authors of papers owe you a deep debt of gratitude for the help that they have received from you in editing their papers; indeed, such trust have they in your judgment that they are almost too liable to leave the whole of the burden of seeing their papers through the press in your hands.

If it were necessary for me to allude to actual geological work done by you, I have only to mention the Index to the first Fifty Volumes of the Quarterly Journal, which was completed by you outside your official hours, and has proved of immense value to all writers in geology. But in handing you this award of the Wollaston Donation Fund, I trust rather that you will receive it as a mark of appreciation by the Council and Fellows of your able and conscientious services to the Society and to geology as Assistant Secretary and Editor of the Journal, and I can only conclude with the hope that we may have the advantage of your services for many years to come.

The President, in handing the Balance of the Proceeds of the Murchison Geological Fund, awarded to Mrs. Elizabeth Gray, of Edinburgh, to Dr. Henry Woodward, F.R.S., for transmission to the recipient, addressed him in the following words:—Dr. Woodward,—

Mrs. Gray has devoted the leisure hours of nearly half a lifetime to collecting in the field and arranging in her cabinets the fossils of the Ordovician and Silurian rocks

of the Girvan district of Ayrshire. The palæontology bears so closely on the structure of this complicated region, that a detailed knowledge of it is indispensable to any geologist who attempts to unravel that structure.

Her collections have been of more than ordinary value, because of the careful record that she has kept from the first of the exact locality and horizon at which each fossil was collected. She has generously placed her specimens at the disposal of all geologists and palæontologists engaged in the study of the Palæozoic rocks and fossils, and a large number of them have been described in the monographs of Davidson, Nicholson, Etheridge, and others. When working in the Girvan district, the officers of the Geological Survey of Scotland checked their own collection by that of Mrs. Gray, and paid a well-earned tribute to its value by publishing in their memoir on the Silurian Rocks of Southern Scotland a full list of all her fossils supplementary to their own. My own personal indebtedness to the collections made by Mrs. Gray and her family, when I was working at the geology of that district, was especially great; and it affords me no ordinary gratification to be able to hand to you, for transmission to her, the Balance of the Proceeds of the Murchison Geological Fund, on behalf of the Council of this Society.

Dr. Woodward, in reply, read the following letter which had been forwarded to him by the recipient:—

"Dear Dr. Woodward,

"I am gratified to learn that you intend to be present at the anniversary meeting of the Geological Society, and I thank you for your kindness in allowing me to nominate you to receive for me on that occasion the Murchison Fund, awarded by the Council of the Society in consideration of what they too generously characterize as 'great services to Geological Science.'

"My work in the Girvan district, among the fossils of the Silurian rocks, has been to me a lifelong pleasure, augmented of late years by the knowledge that my collection has proved of service to the Geological Survey of Scotland, as well as to individual geologists—to name among these but the late Dr. Thomas Davidson.

"It is incumbent on me, however, to record that my husband, the late Mr. Robert Gray, taking a keen interest in my pursuits, shared with me during many years the agreeable task, not only of searching for fossils, but of helping to work them out when found, so that it is difficult for me, in the present circumstances, to repress a pang of regret that he cannot likewise participate in my satisfaction at the Geological Society's very gracious recognition of what, to some extent, was our joint work.

"I value very highly the honour conferred upon me, and beg you to convey to the Council my grateful thanks and sincere acknowledgments."

The President then presented part of the Balance of the Proceeds of the Lyell Geological Fund to Mr. George Edward Dibley, addressing him as follows:—Mr. Dibley,—

You have, for a number of years, devoted the leisure hours of a busy life to the careful collecting of fossils from the Chalk, and have thereby added much to our knowledge of the distribution of species in the several life-zones. The results of these labours have been partly published in the Proceedings of the Geologists' Association, and they include the record of the discovery of a specimen of especial interest, as it is believed to be a representative of the lizard-like Rhynchocephalia, no example of which has been previously recorded from the Chalk.

I have much pleasure in handing to you a moiety of the Balance of the Lyell Fund, which has been awarded to you by the Council of this Society.

Mr. Dibley replied in the following words:—Mr. President,—

I beg to thank the Council of the Geological Society most heartily for their kind appreciation of my efforts to further the accurate knowledge of our Cretaceous geology by the systematic and patient collecting of fossils zone by zone, a method of research so clearly demonstrated by you, Sir, in the older Palæozoic rocks. I can assure you that it is a delight to me to be able to devote each week-end to this branch of natural science; and I only trust that I may be spared to continue my labours on new ground as well as on the old, so that I may be of further use in promoting the advance of geological science.

I may perhaps be allowed to add that, in thanking you for this honour conferred upon me, it gives me especial pleasure to receive it at your hands.

The President, in handing the remainder of the Balance of the Proceeds of the Lyell Geological Fund, awarded to Mr. Sydney S. Buckman, to Dr. Bather, M.A., for transmission to the recipient, addressed him in the following words:—Dr. Bather,—

In the year 1897 the Council of the Geological Society awarded to Mr. Buckman the proceeds of one of their Funds, in acknowledgment of the important work which he had already accomplished among the Jurassic Invertebrata, and of his investigations into the stratigraphical details of their containing formations, expressing their confidence that he would be certain to continue and extend that work.

Their confidence has been more than justified; for since that time, not only has he issued important supplements to his Monograph on the Inferior Oolite Ammonites, published by the Palæontographical Society, and continued his stratigraphical studies on Dundry Hill, and on the Bajocian and Contiguous Deposits in the Northern Cotteswolds, but he has broken new ground in his memoir on "Homœomorphy among Jurassic Brachiopoda," that will doubtless have far-reaching results. He has also published interesting and suggestive papers upon river-development, especially with regard to the genesis of the Severn and the Wye.

For a quarter of a century he has devoted his energies and genius to the advance of geology and palæontology, and each year he has presented to science something valuable and original. The Council of the Geological Society, while sensible of the inadequacy of this recognition of his labours, hope that he will accept it as an earnest of their appreciation of his scientific work.

Dr. Bather, in reply, said:—Mr. President,—

In receiving this award on behalf of my friend Mr. Buckman, it had not been my intention to depart from the precedent that commends silence to the recipients of funds as the most suitable expression of their gratitude; in fact, I took care to leave at home the speech he wrote out for me. But since this somewhat recent precedent has twice been broken this afternoon, I might seem wanting, both in courtesy to yourself and in loyalty to Mr. Buckman, if I did not give the gist of his remarks.

Mr. Buckman is aware that his palæontological work, especially that relating to Ammonites, has met with considerable criticism. He is therefore particularly grateful for this recognition on the part of the Council of the Geological Society. The principles that have animated his work on the Ammonites have been applied by him also to the Brachiopods. They are, in fact, principles that are working a vast revolution in the whole of palæontology. The interpretation of the phenomena of homœomorphy—that is to say, the appearance of species, often at different periods, perplexingly similar in outward form though descended from different stocks—will lead to much more exact identification of fossils. This preciser palæontology, in conjunction with field-work among the Secondary rocks on the lines indicated in Mr. Buckman's last paper contributed to this Society, will, he is confident, have a distinct practical value, since it is bound to throw light on the position of concealed coal-basins. Unfortunately, such wealth as may be obtained in consequence of this purely scientific research will, under present laws, fall not to the nation but to land-owners; least of all will the students, to whose researches it is due, receive any material benefit—except, perhaps, such an award as this, for which I have to offer to you, Sir, Mr. Buckman's sincere thanks.

The President then proceeded to read his Anniversary Address, in which he first gave obituary notices of several Fellows deceased since the last annual meeting, including the Rev. Professor T. Wiltshire (elected a Fellow in 1856), Dr. A. R. C. Selwyn (elected in 1871), Mr. J. C. Mansel-Pleydell (el. in 1857), Mr. W. H. Penning (el. in 1868), Mr. W. Gunn (el. in 1876), Mr. J. Macpherson (el. in 1890), Mr. A. Vaughan Jennings (el. in 1891), Mr. J. Landon (el. in 1887), Mr. A. L. Collins (el. in 1892), Major J. W. Powell, Foreign Correspondent (el. in 1892), Mr. A. Hyatt, Foreign Correspondent (el. in 1897), Lord Pirbright (el. in 1861), Mr. F. Stevenson (el. in 1877), and Dr. Hugh Exton (el. in 1883).

He then dealt with the relation of geology to its fellow-sciences. Astronomy and geology—one the oldest, the other the youngest of the sciences—have both a comparatively small number of adherents and working members. One suggests to the mind of man ideas of infinity, and the other those of eternity; but while the former ideas have found ready acceptance, the latter have had to struggle against much reluctance on the part, not only of the average man, but of physicists and mathematicians, and even of geologists themselves, and this in spite of the fact that some of the most fertile principles of geological science have had their spring in a conviction of the immensity of past time.

Geology has relations with mineralogy, physics, geography, and biology; but though fearlessly acknowledging how much it has borrowed from each of these sciences, it can claim that the debt has in every case been repaid with interest. To mineralogy it has given the associations and relations of minerals in the crystalline rocks; to biology, the strongest proofs of organic evolution and the stages of its advance; to geography, the explanation of the origin of the earth's surface-features, and the foundation of the study sometimes called 'geomorphology'; to physics, the facts with regard to the deformations of the earth's crust, which still await a theoretical explanation.

The study of geology shows that the corporate geological organism has three necessary functions—research, practice, and education. So long as all three functions are naturally and healthfully performed, so long will geology live and flourish. The work and influence of Werner and De la Beche show that the progress of the science is at its swiftest and surest when none of the three functions suffer from disuse.

In its relations to the thoughts of mankind and ideas of life, what gives character and its especial colour to the science of geology is that it is the exponent, or practically the discoverer, of the idea of continuous evolution, "for he discovers who proves." To a student who has gone through a geological training and appreciated its meaning, the idea of slow and continuous evolution becomes part and parcel of his mental constitution, and he carries this conception into his other studies. In all cases he is on the watch for those simple natural causes that are capable of the present accumulated effects; he is watching the development of a living being growing up, as it were, before his mental vision. It is therefore to be desired that some knowledge of this kind should reach the ordinary man of education and leisure, as well as the specialist, for it tends to restore the loss of balance due to the self-absorptive and introspective tendency of much of our present-day culture.

Some such geonomic training or earth-knowledge is essential in any complete scheme of education—at first hardly differentiated into geology and geography, but later passing on to the study of topography, geography, and geology. The training should be in the early stages experimental and practical, bringing out all that can be shown upon maps and learnt from them; but the didactic side must

not be neglected, particularly in those years of life when a student is most qualified to profit by it, because the facts of science are so many, and the grandest conclusions are so dependent on the higher stages of knowledge.

The veil of ignorance and of traditional opinion which hid from the view of the Middle Ages the wonders which geology has since revealed, was so opaque that, until the close of the eighteenth century, no light could penetrate beyond. But so old and flimsy was it that, when once the strong hand of the geologist had torn it, it was rent from top to bottom, and in the flood of light which entered discovery followed discovery in endless succession. These discoveries have benefited not only geology but all its fellow-sciences, and have been of supreme importance to man himself.

Therefore, as geology goes hopefully forward into the new era now opening out before it, its students should never forget that their science is not only the interpreter of Nature, but also the servant of Humanity.

The ballot for the Council and Officers was taken, and the following were declared duly elected for the ensuing year:—*Council:* The Right Hon. Lord Avebury, P.C., D.C.L., LL.D., F.R.S., F.L.S.; F. A. Bather, M.A., D.Sc.; W. T. Blanford, LL.D., F.R.S.; Sir John Evans, K.C.B., D.C.L., LL.D., F.R.S.; Professor E. J. Garwood, M.A.; Sir Archibald Geikie, D.Sc., D.C.L., LL.D., F.R.S. L.&E.; Professor T. T. Groom, M.A., D.Sc.; Alfred Harker, Esq., M.A., F.R.S.; R. S. Herries, Esq., M.A.; R. Logan Jack, LL.D.; Professor J. W. Judd, C.B., LL.D., F.R.S.; Percy F. Kendall, Esq.; Professor Charles Lapworth, LL.D., F.R.S.; Lieut.-General C. A. McMahon, F.R.S.; J. E. Marr, Esq., M.A., F.R.S.; Professor H. A. Miers, M.B., F.R.S.; H. W. Monckton, Esq., F.L.S.; E. T. Newton, Esq., F.R.S.; G. T. Prior, Esq., M.A.; Professor H. G. Seeley, F.R.S., F.L.S.; Professor W. J. Sollas, M.A., D.Sc., LL.D., F.R.S.; J. J. H. Teall, Esq., M.A., F.R.S.; Professor W. W. Watts, M.A.

Officers:—President: Prof. Charles Lapworth, LL.D., F.R.S. *Vice-Presidents:* Sir Archibald Geikie, D.Sc., D.C.L., LL.D., F.R.S. L. & E.; Professor H. A. Miers, M.A., F.R.S.; E. T. Newton, Esq., F.R.S.; and J. J. H. Teall, Esq., M.A., F.R.S. *Secretaries:* R. S. Herries, Esq., M.A., and Professor W. W. Watts, M.A. *Foreign Secretary:* Sir John Evans, K.C.B., D.C.L., LL.D., F.R.S., F.L.S. *Treasurer:* W. T. Blanford, LL.D., F.R.S.

The thanks of the Fellows were unanimously voted to the retiring Vice-Presidents, Mr. J. E. Marr and Professor H. G. Seeley; and to the retiring Members of Council, Mr. W. H. Hudleston, the Right Rev. John Mitchinson, Dr. D. H. Scott, Mr. A. Sopwith, and Dr. Henry Woodward.

II.—February 25th, 1903.—Professor Charles Lapworth, LL.D., F.R.S., President, in the Chair. The following communications were read:—

1. "On the Occurrence of *Dictyozamites* in England, with Remarks on European and Eastern Floras." By Albert Charles Seward, Esq., M.A., F.R.S., F.L.S., F.G.S., Fellow of Emmanuel College, Cambridge.

The specimens described as a new species of *Dictyozamites* were obtained from a bed of ironstone, low down in the Estuarine Series, on the northern face of the Upleatham outlier, near Marske-by-the-Sea, by the Rev. John Hawell, F.G.S. The genus is also found in

the Rajmahal Series of India, in Central Japan, and at Bornholm. Its probable taxonomic position is best expressed by placing it as a member of the Cycadophyta.

The author proceeds to a comparison of the Bornholm, Indian, Japanese, and English floras; and as resemblances are masked by the use of different generic or specific names for plants which are either identical or represent closely allied members of the same family, a special list of these floras has been prepared, in which, while the names at present in use are indicated, it is pointed out where obscured identities or resemblances exist. From this comparison the author concludes that there was a greater similarity between the vegetation of Eastern and Western regions, during part at least of the Mesozoic Era, than is usually admitted; while the differences between Mesozoic floras of approximately the same geological age are for the most part slight and unimportant, when their wide geographical separation is considered. Equisetaceous plants are practically ubiquitous; several ferns of apparently the same species occur in the Far East and in Western Europe; cycadaceous plants are represented by cosmopolitan types, and the same may be said of the genus *Araucarites* and other members of the Coniferæ. The most noteworthy exceptions are afforded by the Mesozoic representatives of the two isolated recent ferns *Matonia* and *Dipteris*; these two families—each with a surviving genus—played a conspicuous part in the vegetation of the Rhætic and succeeding Jurassic Epochs in Europe, and to a less extent in North America, but there are no satisfactory records of their existence in India or Japan. A similar state of things is illustrated by the Ginkgoales, the class of which the 'maidenhair-tree' of China and Japan forms the solitary survivor; the abundance of both *Ginkgo* and *Baiera* in the Mesozoic of Europe is in striking contrast to their almost complete absence in India.

2. "The Amounts of Nitrogen and Organic Carbon in some Clays and Marls." By Dr. N. H. J. Miller, F.C.S. (Communicated by Sir John Evans, K.C.B., D.C.L., F.R.S., For. Sec. G.S.)

Analyses of soils are given to show that, under most conditions, decaying vegetable matter in soil tends to become more nitrogenous, on account of the greater ease with which gaseous compounds are formed with carbon than with nitrogen. Hilgard's experiments throw light on the effects of extreme conditions of climate, the amount of soluble humus being much greater in soils in humid than in arid climates; thus, although the total amount of soluble nitrogen does not vary much, the percentage of it in the humus varied very considerably in the two cases. The large areas of peat-land known as 'Hochmoor' contain larger proportions of carbon and nitrogen at depths of 7 and 14 feet than at the surface. The organic matter of soils is of two kinds—the humous portion and the bituminous; the latter being regarded as belonging to the original deposit from which the soil is derived. Analyses of soils and subsoils are given to illustrate this point. Further light on this subject is derived from the analysis of a series of specimens from the following deposits,

obtained through the kindness of Sir Archibald Geikie from borings in the possession of the Geological Survey: Lower Lias, Oxford Clay, Kimmeridge Shale, Purbeck and Wealden strata, Gault, Chalk Marl, and London Clay. Apart from the interest due to the great depths from which the samples were obtained, and the evidence which they afford of the enormous accumulations of combined nitrogen, they possess the further and greater value of representing the materials out of which large areas of soils have been derived. Calcium-carbonate varies from 82·1 to 0 per cent., organic carbon from 1·229 to 0·229, and nitrogen from 0·068 to 0·021; the highest proportion of carbon to nitrogen is 40·3 to 1, and the lowest 8·9 to 1. It would be important to determine, in the case of these older deposits, whether any of the organic matter at all is in the form of humus.

III.—Mineralogical Society, February 3rd.—Professor H. A. Miers, F.R.S., Vice-President, in the Chair. Mr. L. Fletcher gave an account of the fall of a meteoric stone on August 22nd, 1902, at Caratash, Smyrna; and also contributed a note on the history of the mass of meteoric iron found in the neighbourhood of Capera, Patagonia. Mr. H. L. Bowman gave the results of determinations of the refractive indices of pyromorphite and vanadinite by means of artificially ground prisms having an angle of about 30°. For red light the refractive indices of pyromorphite were $\omega = 2{\cdot}139$, $\varepsilon = 2{\cdot}124$; and of vanadinite, $\omega = 2{\cdot}354$, $\varepsilon = 2{\cdot}299$. Mr. T. V. Barker described quartz crystals of peculiar habit which were collected by Lieut. E. G. Spencer-Churchill near De Aar, South Africa. Two crystals were remarkable as exhibiting faces seldom observed on quartz, one in the zone *mz* and the other in the zone *rz*.

IV. — Edinburgh Geological Society. Special Meeting, 5th February, 1903. Dr. Horne, F.R.S., in the Chair. Lecture on "The Fassa-Monzoni District, or Simultaneous Duplex Crust Movements." By Mrs. Ogilvie Gordon, D.Sc., Ph.D., Aberdeen.

The lecture was illustrated by Mrs. Gordon's lantern views, geological maps and sections, rock specimens, and mineralogical slides. In describing the succession of Triassic strata Mrs. Gordon pointed out two distinct advances made by her work—(1) She had discovered the presence of Wengen-Cassian marls with characteristic fossils in the midst of the Middle Triassic limestones, whereas hitherto these fossiliferous marls had been reported to be absent in Fassa; (2) she had determined the presence of a definite band of fossiliferous marls and crinoidal and oolitic limestones between the Lower and Middle Trias, as a constant member in all undisturbed sections. Hitherto these limestones had been regarded as unfossiliferous, and described as a rarely present, abnormal facies of the lower horizons of Middle Triassic limestones. The establishment of this definite passage zone between Lower and Middle Trias was an important addition to the geology of South Tyrol. Further, it corresponded to the horizon of 'Reichenhall limestone' and the 'Myophoria beds' in North Tyrol, and probably also to the well-known 'Röth' horizon in the North German Trias. Throughout

the Tertiary crust movements in the Alps this passage zone had been the great crush-zone of the district. It occurred in Fassa below a massive development of calcareous rocks, and above an almost equal thickness of mixed deposits; it was therefore a well-marled 'critical' zone within the earth's crust, interleaved between rock material, presenting strongly contrasted physical characters. The maximum deformational effects had been attained at this zone, and in the other leading 'critical' zone presented by the Wengen-Cassian marls. Innumerable planes of overthrust and downslip had developed within these bands, some with only 10 degs. to 20 degs. inclination, others much steeper. Vast eruptions of molten rock had found their way into these deformational zones, and consolidated in the form of wide sheets and sills at those definite horizons within the Triassic succession. Thus, one of the general results of her detailed survey had been to disprove the previous conception that the porphyrite rocks in Fassa had originated as surface outflows in Triassic time, and to show that they had been intruded into the local fault lines and planes of crust deformation which developed during middle and late Tertiary Alpine movements. A similar result had been obtained several years ago by her for the area on the north. The previous investigators had failed to recognize the presence of the innumerable crust planes with extremely low inclination, and consequently overlooked the correlation of the igneous invasions with pre-existent deformational structures. After indicating on the map the complete sequence of the igneous rocks at Monzoni, Mrs. Gordon proceeded to describe her new results regarding cross-fold formation. Several folding movements had affected this district. In the first place, undulations directed east and west had formed with a steep southern face and a long northern slope, the width of an undulation being about $4\frac{1}{2}$ miles. These had been deformed by oblique cross-folds, which developed simultaneously along two directions, E.N.E.–W.S.W. and W.N.W.–E.S.E. During these movements the steep south faces of the original plications were overthrust towards S.S.E. and S.S.W., and the first inrush of molten rock occurred into zones of crust attenuation and fracture. Still later, another duplex system of cross-folds was superinduced rectangularly upon the earlier in N.N.W.–S.S.E. and N.N.E.–S.S.W. directions. Overthrusts and shear-slips took place again, and fragmented the previous thrust masses and igneous intrusions. Mrs. Gordon showed by reference to her map that the most intense effects of crust deformation had been coeval with this advanced stage in the superposition of duplex deformational systems upon the original and fundamental east-west undulations. A subsequent epoch of crust adjustment and surface erosion had ensued, characterized by local subsidences taking place pre-eminently along the previous crust fractures. Local crumplings had then occurred around large masses of igneous rock or the larger deformation fragments of Triassic limestone. Small igneous intercalations of highly differentiated rock materials accompanied these inthrows. Mrs. Gordon's interpretation of this remarkable series of cross-folds was based upon the principle of the simultaneous action

of paired resultant strains, acting along N.E.–S.W. and N.W.–S.E. directions, the precise directive angle varying in proportion as the east-west or the north-south stresses due to crust compression were the more powerful, and also in accordance with particular local modifications of the regional strains. At the close a vote of thanks was cordially given to Mrs. Gordon.

CORRESPONDENCE.

EOLITHS FROM SOUTH AND SOUTH-WEST ENGLAND.

Sir,—Kindly insert the following correction and addition to my paper on "Eoliths from South and South-West England" in the March number.

1. *Corrigendum.*—Instead of Bat's Corner read *Kettle's Corner,* Parsonage Farm (Chapel Croft Field), near Ash. Mr. Harrison informs me that it is so marked in the 6 inch map of the district. Bat's Corner was the name given me on December 24th, 1894, when I visited the pit with Mr. Harrison, but as tenants change so do the names of their farms. Probably Kettle was the name of a former tenant.

2. *Addendum* (*Bibliography*), with sincere apologies for the omission.

1899. *Newton, E. T.*—Presidential Address to the Geologists' Association, February 5th, 1897: Proc. Geol. Assoc., vol. xv, pp. 69–72.

1902. *Haddon, A. C.*—"Early Man and his Life," third paper: National Home Reading Union Magazine, p. 45.

Pyrford, *March 6th*, 1903. R. Ashington Bullen.

THE ORIGIN OF THE ARCHÆAN ROCKS.

Sir,—Some references to the Archæan rocks made by Mr. G. W. Bulman in the Geological Magazine for March (p. 126) call for a word of comment. I do not understand what he means by "pre-Archæan deposits." There are no rocks older than the Archæan, whether we use the term as equivalent to "pre-Cambrian" or limit it to the "Fundamental Complex." Then he remarks that "Geologists are yet sorely perplexed with the problem of the Archæan rocks. They have not yet decided whether they are metamorphosed ordinary sediments, [or ?] part of the original solidified crust of the earth, or chemical precipitates from a hot primitive ocean." But these alternatives are *not* the problem. There is no perplexity whatever about a large proportion of the Archæan rocks. The Longmyndian and Torridonian are known to be mainly sedimentary; the groups identified as Pebidian, Uriconian, and Charnian are known to be predominantly volcanic; and the rock-masses called Malvernian and Hebridean are generally admitted to be igneous plutonics. A similar variety of origin has also been ascertained with respect to many of the Archæan rocks of North America, Bohemia, and elsewhere. There are, of course, some Archæan rock-groups whose genesis has not yet been determined with certainty; but these are only a *part* of "the problem of the Archæan rocks."

C. Callaway.

Cheltenham, *March 5th*, 1903.